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# DEVELOPMENT DOCUMENT FOR EFFLUENT LIMITATIONS GUIDELINES AND NEW SOURCE PERFORMANCE STANDARDS FOR THE FISH MEAL, SALMON, BOTTOM FISH, CLAM, OYSTER, SARDINE, SCALLOP, HERRING, AND ABALONE SEGMENT OF THE CANNED AND PRESERVED FISH AND SEAFOOD PROCESSING INDUSTRY POINT SOURCE CATEGORY

ENVIRONMENTAL PROTECTION AGENCY

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# Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the

# Fish Meal, Salmon, Bottom Fish, Clam, Oyster, Sardine, Scallop, Herring, and Abalone

# Segment of the Canned and Preserved Fish and Seafood Processing Industry Point Source Category

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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Effluent limitations are set forth for the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available" and the "Best Available Technology Economically Achievable" which must be achieved by existing point sources by July 1, 1977 and July 1, 1983 respectively. The "Standards of Performance for New Sources" set forth a degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods or other alternatives. The regulations are based on the best identified primary or physical-chemical treatment technology currently available for discharge into navigable water bodies by July 1, 1977 and for new source performance standards. This technology is generally represented by fine screens and air flotation. The regulations for July 1, 1983 are based on the best identified physical-chemical and secondary treatment and in-plant control as represented by significantly reduced water use and enhanced treatment efficiencies in existing systems, as well as new systems. This technology is generally represented by air flotation, aerated lagoons, or activated sludge.

Supportive data and rationale for development of the effluent limitations and standards of performance are contained in this report.

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# ABSTRACT

This document presents the findings of an extensive study of the fish meal, salmon, bottom fish, clam, oyster, sardine, scallop, herring, and abalone segment of the canned and preserved fish and seafood processing industry of the United States to develop effluent limitations for point source and new source standards of performance in order to implement Sections 304(b) and 306 of the Federal Water Pollution Control Act Amendments of 1972 (the Act).

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Supportive data and rationale for development of the effluent limitations and standards of performance are contained in this report.

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# SECTION I

# CONCLUSIONS

For the purpose of establishing effluent limitations guidelines for existing sources and standards of performance for new sources, the canned and preserved seafood processing industry covered in this study was divided into 19 subcategories:

1) Fish meal processing
2) Alaskan hand-butchered salmon processing
3) Alaskan mechanized salmon processing
4) West Coast hand-butchered salmon processing
5) West Coast mechanized salmon processing
6) Alaskan bottom fish processing
7) Non-Alaskan conventional bottom fish processing
8) Non-Alaskan mechanized bottom fish processing
9) Hand-shucked clam processing
10) Mechanized clam processing
11) West Coast hand-shucked oyster processing
12) Atlantic and Gulf Coast hand-shucked oyster processing
13) Steamed/canned oyster processing
14) Sardine processing
15) Alaskan scallop processing
16) Non-Alaskan scallop processing
17) Alaskan herring fillet processing
18) Non-Alaskan herring fillet processing
19) Abalone processing

The major criteria for the establishment of the categories were:

1) variability of raw product supply;
2) variety of the species being processed;
3) degree of preprocessing;
4) manufacturing process and subprocesses;
5) form and quality of finished product;
6) location of plant;
7) nature of operation (intermittent vs. continuous); and
8) amenability of the waste to treatment.

The wastes from all subcategories are amenable to biological waste treatment under certain conditions and no materials harmful to municipal waste treatment processes (with adequate operational controls) were found.

A determination of this study was that the level of waste treatment throughout the seafood industry is generally inadequate, except for the fish meal production industry where there are several exemplary plants. At the present time many plants in the contiguous states and almost all Alaskan plants discharge solid and liquid wastes directly into the receiving waters, others utilize coarse screening techniques to remove gross solids from the effluent streams prior to discharge. Technology exists , however, for the successful reduction of respective wastewater constituents within the industry to the point where most plants can be in compliance by July 1, 1977. The 1977 limitations are based on technology which can be utilized within the economic capability of the industry. For the contiguous states the technology basis includes fine screening, "good housekeeping" practices, and barging; for Alaska the technology consists of fine screening and barging of solids in non-remote areas, and comminutor or grinders in remote areas. In addition to the aforementioned technology, the basis for the 1983 and new source performance standards includes physical/chemical and secondary treatment and the adoption of in-plant controls as represented by significantly reduced water use and enhanced treatment efficiencies in existing systems, as well as new systems. Because waste treatment, in-plant waste reduction, and effluent management are in their infancy in this industry, rapid progress is expected to be made by the industry in the next four to six years.

The regulated parameters include total suspended solids, oil and grease, and pH for the limitation based on screening systems; for physical/chemical and biological systems, BOD5 is utilized also as a regulated parameter. Particle size is the regulated parameter for limitations based on comminuters or grinders.

# SECTION II

## RECOMMENDATIONS

Limitations recommended for process waste waters discharged to navigable waters are based on the reduction of wastewater flows and loads through in-plant housekeeping and modifications and the characteristics of well operating screens, dissolved air flotation units, aerated lagoons, and extended aeration systems. Parameters designated to be of significant importance to warrant regulation in this industry, are 5-day biochemical oxygen demand (BOD-5), total suspended solids (TSS), grease and oil (G&O), and pH.

The effluent limitations based on the best practicable control technology currently available (BPCTCA) are presented in Table 1; the effluent limitations based on the best available technology economically achievable (BATEA) in Table 2; and new source performance standards, in Table 3.

## TABLE 1
## JULY 1, 1977 EFFLUENT LIMITATIONS

Parameter (kg/kkg or lbs/1000 lbs seafood processed)

| Subcategory | Technology (BPCTCA) | BOD5 | | TSS | | Grease & Oil | |
|---|---|---|---|---|---|---|---|
| | | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg |
| O. Fish Meal | | | | | | | |
| 1. with solubles unit | H | 4.7 | 3.5 | 2.3 | 1.3 | 0.80 | 0.63 |
| 2. w/o solubles unit | B | 3.5 | 2.8 | 2.6 | 1.7 | 3.2 | 1.4 |
| P. AK hand-butchered salmon | | | | | | | |
| 1. non-remote | H,S,B | - | - | 1.7 | 1.4 | 0.20 | 0.17 |
| 2. remote | Grind | * | * | * | * | * | * |
| Q. AK mechanized salmon | | | | | | | |
| 1. non-remote | H,S,B | - | - | 27 | 22 | 27 | 10 |
| 2. remote | Grind | * | * | * | * | * | * |
| R. West Coast hand-butchered salmon | H,S | - | - | 1.7 | 1.4 | 0.20 | 0.17 |
| S. West Coast mechanized salmon | H,S | - | - | 27 | 22 | 27 | 10 |
| T. AK bottom fish | | | | | | | |
| 1. non-remote | H,S,B | - | - | 3.0 | 1.9 | 4.3 | 0.56 |
| 2. remote | Grind | * | * | * | * | * | * |
| U. Non-AK conventional bottom fish | H,S | - | - | 2.1 | 1.6 | 0.55 | 0.40 |
| V. Non-AK mechanized bottom fish | H,S | - | - | 14 | 10 | 5.7 | 3.3 |
| W. Hand-shucked clams | H,S | - | - | 59 | 18 | 0.60 | 0.23 |

Table 1 (cont'd) July 1, 1977 Effluent Limitations

|  |  | Parameter (kg/kkg or lbs/1000 lbs seafood processed) |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
|  |  | BOD5 |  | TSS |  | Grease & Oil |  |
| Subcategory | Technology (BPCTCA) | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg |
| X. Mechanized clams | H,S | - | - | 90 | 15 | 4.2 | 0.97 |
| Y. Pacific Coast hand-shucked oysters** | H,S | - | - | 37 | 35 | 1.7 | 1.6 |
| Z. East & Gulf Coast hand-shucked oysters** | H,S | - | - | 19 | 15 | 0.77 | 0.70 |
| AA. Steamed/Canned oysters** | H,S | - | - | 270 | 190 | 2.3 | 1.7 |
| AB. Sardines |  |  |  |  |  |  |  |
| 1. dry conveying | H,S,GT*** | - | - | 36 | 10 | 3.5 | 1.4 |
| 2. wet flume | H,S,GT*** | - | - | 48 | 16 | 6.3 | 2.8 |
| AC. AK scallops** |  |  |  |  |  |  |  |
| 1. non-remote | H,S,B | - | - | 6.0 | 1.4 | 7.7 | 0.24 |
| 2. remote | Grind | * | * | * | * | * | * |
| AD. Non-AK scallops** | H,S | - | - | 6.0 | 1.4 | 7.7 | 0.24 |
| AE. AK herring fillet |  |  |  |  |  |  |  |
| 1. non-remote | H,S,B | - | - | 32 | 24 | 27 | 10 |
| 2. remote | Grind | * | * | * | * | * | * |

Table 1 (cont'd) July 1, 1977 Effluent Limitations

Parameter (kg/kkg or lbs/1000 lbs seafood processed)

| Subcategory | Technology (BPCTCA) | BOD5 Daily Max | BOD5 Max 30-Day avg | TSS Daily Max | TSS Max 30-Day avg | Grease & Oil Daily Max | Grease & Oil Max 30-Day avg |
|---|---|---|---|---|---|---|---|
| AF. Non-AK herring fillet | H,S | - | - | 32 | 24 | 27 | 10 |
| AG. Abalone | H,S | - | - | 27 | 15 | 2.2 | 1.4 |

H = housekeeping; S = screen; DAF = dissolved air flotation without chemical optimization;
B = barge solids; GT = grease trap

*No pollutants may be discharged which exceed 1.27 cm (0.5 inch) in any dimension

**Effluent limitations in terms of finished product

***Effluent limitations are based on treatment of the pre-cook water by screening and skimming of free oil, and screening for the remainder of the effluent

## Table 2
## July 1, 1983 Effluent Limitations

| Subcategory | Technology (BATEA) | Parameter (kg/kkg or lbs/1000 lbs seafood processed) BOD5 Daily Max. | BOD5 Max. 30-Day avg. | TSS Daily Max. | TSS Max. 30-Day avg. | Grease & Oil Daily Max. | Grease & Oil Max. 30-Day avg. |
|---|---|---|---|---|---|---|---|
| O. Fish meal | IP | 4.0 | 2.6 | 2.3 | 1.3 | 0.80 | 0.63 |
| P. Ak hand-butchered salmon | IP,S,B | - | - | 1.5 | 1.2 | 0.18 | 0.15 |
| Q. Ak mechanized salmon | | | | | | | |
| 1. non-remote | IP,S,DAF,B | 16 | 13 | 2.6 | 2.2 | 2.6 | 1.0 |
| 2. remote | IP,S,B | - | - | 26 | 21 | 26 | 10 |
| R. West Coast hand-butchered salmon | IP,S,DAF | 1.2 | 1.0 | 0.15 | 0.12 | 0.045 | 0.018 |
| S. West Coast mechanized salmon | IP,S,DAF | 16 | 13 | 2.6 | 2.2 | 2.6 | 1.0 |
| T. Ak bottom fish | IP,S,B | - | - | 1.9 | 1.1 | 2.6 | 0.34 |
| U. Non-Ak conventional bottom fish | IP,S,AL | 0.73 | 0.58 | 1.5 | 0.73 | 0.04 | 0.03 |
| V. Non-Ak mechanized bottom fish | IP,S,DAF | 6.5 | 5.3 | 1.1 | 0.82 | 0.46 | 0.26 |
| W. Hand-shucked clams | IP,S | - | - | 55 | 17 | 0.56 | 0.21 |
| X. Mechanized clams | IP,S,AL | 15 | 5.7 | 26 | 4.4 | 0.40 | 0.092 |

Table 2 (Cont'd)
Proposed Ju'y 1, 1983 Effluent Limitations

| Subcategory | Technology (BATEA) | Parameter (kg/kkg or lbs/1000 lbs seafood processed) | | | | | |
|---|---|---|---|---|---|---|---|
| | | BOD5 | | TSS | | Grease & Oil | |
| | | Daily Max. | Max. 30-Day avg. | Daily Max. | Max. 30-Day avg. | Daily Max. | Max. 30-Day avg. |
| Y. Pacific Coast hand-shucked oysters* | H,S | - | - | 37 | 35 | 1.7 | 1.6 |
| Z. East Gulf Coast hand-shucked oysters* | H,S | - | - | 19 | 15 | 0.77 | 0.70 |
| AA. Steamed/Canned oysters* | IP,S,AL | 67 | 17 | 56 | 39 | 0.84 | 0.42 |
| AB. Sardines | IP,S,DAF** | - | - | 36 | 10 | 1.3 | 0.52 |
| AC. Ak scallops* | IP,S,B | - | - | 5.7 | 1.4 | 7.3 | 0.23 |
| AD. Non-Ak scallops* | IP,S | - | - | 5.7 | 1.4 | 7.3 | 0.23 |
| AE. Ak herring fillets | | | | | | | |
| 1. non-remote | IP,S,DAF,B | 6.8 | 6.2 | 2.3 | 1.8 | 2.0 | 0.73 |
| 2. remote | IP,S,B | - | - | 23 | 18 | 20 | 7.3 |

Table 2 (Cont'd)
Proposed July 1, 1983 Effluent Limitations

| Subcategory | Technology (BATEA) | Parameter (kg/kkg or lbs/1000 lbs seafood processed) BOD5 Daily Max. | BOD5 Max. 30-Day avg. | TSS Daily Max. | TSS Max. 30-Day avg. | Grease & Oil Daily Max. | Grease & Oil Max. 30-Day avg. |
|---|---|---|---|---|---|---|---|
| AF. Non-Ak herring fillets | IP,S,DAF | 6.8 | 6.2 | 2.3 | 1.8 | 2.0 | 0.73 |
| AG. Abalone | IP,S | - | - | 26 | 14 | 2.1 | 1.3 |

IP = in-plant process changes; S = screen; DAF = dissolved air flotation with chemical optimization;
AL = aerated lagoon; EA = extended aeration; B = barge solids

*Effluent Limitations in terms of finished product

**Effluent limitations based on DAF treatment of the can wash and pre-cook water, and screening for the remainder of the effluent

## TABLE 3
## NEW SOURCE PERFORMANCE STANDARDS

Parameter (kg/kkg or lbs/1000 lbs seafood processed)

| Subcategory | Technology | BOD5 Daily Max | BOD5 Max 30-Day avg | TSS Daily Max | TSS Max 30-Day avg | Grease & Oil Daily Max | Grease & Oil Max 30-Day avg |
|---|---|---|---|---|---|---|---|
| O. Fish meal | IP | 4.0 | 2.9 | 2.3 | 1.3 | 0.80 | 0.63 |
| P. Ak hand-butchered salmon | | | | | | | |
| 1. non-remote | IP,S,B | - | - | 1.5 | 1.2 | 0.18 | 0.15 |
| 2. remote | grind | * | * | * | * | * | * |
| O. Ak mechanized salmon | | | | | | | |
| 1. non-remote | IP,S,B. | - | - | 26 | 21 | 26 | 10 |
| 2. remote | grind | * | * | * | * | * | * |
| R. West Coast hand-butchered salmon | IP,S,DAF | 1.7 | 1.4 | 0.46 | 0.37 | 0.058 | 0.023 |
| S. West Coast mechanized salmon | IP,S,DAF | 36 | 32 | 7.9 | 6.5 | 3.8 | 1.5 |
| T. Ak bottom fish | | | | | | | |
| 1. non-remote | IP,S,B | - | - | 1.9 | 1.1 | 2.6 | 0.34 |
| 2. remote | grind | * | * | * | * | * | * |
| U. Non-Ak conventional bottom fish | IP,S,AL | 0.73 | 0.58 | 1.5 | 0.73 | 0.04 | 0.03 |
| V. Non-Ak mechanized bottom fish | IP,S,DAF | 9.1 | 7.4 | 3.3 | 2.5 | 0.68 | 0.39 |
| W. Hand-shucked clams | IP,S | - | - | 55 | 17 | 0.56 | 0.21 |

Table 3 (Cont'd) New Source Performance Standards

| Subcategory | Technology | Parameter (kg/kkg or lbs/1000 lbs seafood processed) | | | | | |
|---|---|---|---|---|---|---|---|
| | | BOD5 | | TSS | | Grease & Oil | |
| | | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg |
| X. Mechanized clams | IP,S,AL | 15 | 5.7 | 26 | 4.4 | 0.40 | 0.092 |
| Y. Pacific Cost hand-shucked oysters** | H,S | - | - | 37 | 35 | 1.7 | 1.6 |
| Z. East & Gulf Coast hand-shucked oysters** | H,S | - | - | 19 | 15 | 0.77 | 0.70 |
| AA. Steamed/Canned oysters** | IP,S,AL | 67 | 17 | 56 | 39 | 0.84 | 0.42 |
| AB. Sardines | IP,S,DAF*** | - | - | 36 | 10 | 1.4 | 0.57 |
| AC. Ak scallops** | | | | | | | |
| 1. non-remote | IP,S,B | - | - | 5.7 | 1.4 | 7.3 | 0.23 |
| 2. remote | grind | * | * | * | * | * | * |
| AD. Non-Ak scallops | IP,S | - | - | 5.7 | 1.4 | 7.3 | 0.23 |
| AE. Ak herring filllets | | | | | | | |
| 1. non-remote | IP,S,B | - | - | 23 | 18 | 20 | 7.3 |
| 2. remote | grind | * | * | * | * | * | * |

Table 3 (Cont'd) New Source Performance Standards

| | | Parameter (kg/kkg or lbs/1000 lbs seafood processed) | | | | | |
|---|---|---|---|---|---|---|---|
| | | BOD5 | | TSS | | Grease & Oil | |
| Subcategory | Technology | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg |
| AF. Non-Ak herring fillets | IP,S,DAF | 16 | 15 | 7.0 | 5.2 | 2.9 | 1.1 |
| AG. Abalone | IP,S | - | - | 26 | 14 | 2.1 | 1.3 |

IP = in-plant process changes; S = screen; DAF = dissolved air flotation without chemical optimization; AL = aerated lagoon; EA = extended aeration; B = barge solids

*No pollutants may be discharged which exceed 1.27 cm (0.5 inch) in any dimension

**Effluent limitations in terms of finished product

***Effluent limitations based on DAF treatment of the can wash and pre-cook water, and screening for the remainder of the effluent

## SECTION III

## INTRODUCTION

### PURPOSE AND AUTHORITY

Section 301(b) of the Federal Water Pollution Control Act Amendments of 1972 (the Act) requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the E.P.A. Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable and which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants. Section 307 (b) and (c) of the Act requires the achievement of pretreatment standards for existing and new sources for introduction of pollutants into publicly owned treatment works for those pollutants which are determined not to be susceptible to treatment by such treatment works or which would interfere with the operation of such treatment.

Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act, regulations providing for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operational methods and other alternatives. The regulations developed herein set forth effluent limitations pursuant to Section 304(b) of the Act for the fish meal, salmon, bottom fish, clam, oyster, sardine, scallop, herring and abalone segment of the canned and preserved fish and seafood processing point source category. The effluent limitations for the shrimp, tuna, crab, and catfish segment of the industry were promulgated in the June 26, 1974, Federal Register (39 F.R. 23134), and amended in the January 30, 1975, Federal Register (40 F.R. 4582).

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b)(1)(A) of the Act, to propose regulations establishing federal standards of performance for new sources within such categories. The Administrator published in the *Federal Register* of January 16, 1973 (38 F.R. 1624), a list of 27 categories. Publications of the list constituted announcement of the Administrator's intention to establish, under Section 306, standards of performance applicable to new sources for the canned and preserved .fish and seafood point source category, which was included in the list published January 16, 1973.

## SCOPE OF STUDY

The scope of this study is defined as the "remainder of the industry" not included in the promulgated regulations covering farm-raised catfish, crab, shrimp and tuna (39 F.R. 23134). The species specifically mentioned are: oyster, lobster, clam, bottom fish, the oily species such as menhaden, anchovy, herring, and salmon. The "industry" to be covered by both phases is defined as falling into SIC 2031, Canned and Cured Seafood, and SIC 2036, Fresh and Frozen Packaged Seafood. More complete definitions of these two classifications as obtained from the *1972 Standard Industrial Classification Manual* are quoted below. It was noted that SIC 2031 and SIC 2036, as defined in the Department of Commerce *1967 Census of Manufacturers*, Publication MC67 (2)-20C, were changed to SIC 2091 and SIC 2092 respectively in the *1972 S.I.C. Manual*.

### SIC 2091 - Canned and Cured Fish and Seafoods

"Establishments primarily engaged in cooking and canning fish, shrimp, oysters, clams, crabs, and other seafood, including soups; and those engaged in smoking, salting, drying or otherwise curing fish for the trade. Establishments primarily engaged in shucking and packing fresh oysters in nonsealed containers, or in freezing and packaging fresh fish, are classified in Industry 2092."

Canned fish, crustacea, and mollusks
Caviar: canned and preserved
Clam bouillon, broth, chowder, juice: bottled or canned
Codfish: smoked, salted, dried, and pickled
Crab meat, canned and preserved
Finnan haddie (smoked

Fish, canned
Fish egg bait, canned
Herring: smoked, salted, dried, and pickled
Mackerel: smoked, salted, dried, and pickled
Oysters, canned and preserved
Salmon: smoked, salted, dried, canned and pickled
Sardines, canned
Seafood products, canned

haddock)
Fish: boneless, cured dried, pickled, salted, and smoked
Shellfish, canned
Shrimp, canned
Soup, seafood: canned
Tuna fish, canned

SIC 2092 - Fresh or Frozen Packaged Fish and Seafoods

Crab meat, fresh: packed in non-sealed containers
Crab meat picking
Fish fillets
Fish: fresh, quick frozen, and cold pack (frozen)--packaged
Fish sticks
Frozen prepared fish
Oysters: fresh, shucked and packed in non-sealed containers
Seafood: fresh, quick frozen, and cold pack (frozen) --packaged
Shellfish, quick frozen and cold pack (frozen)
Shrimp, quick frozen and cold pack (frozen)
Soups, seafood: frozen

The reduction of the oily species for animal feed, oils and solubles is not included in either classification, but is contained in this report. Therefore, the study encompassed the following segments of the United States fishery industry:

1) All processes falling into either SIC 2031 (2091) or 2036 (2092), which are considered to produce a significant waste load; and

2) the reduction of oily species such as menhaden and anchovy for fish meal, oil and solubles, including the reduction of fish waste when processed at the same facility.

Fish or shellfish which are canned or processed fresh or frozen for bait or pet food were not included in this study unless the operation was an integral part of a process covered by item number one or two, above. The distribution of landings between fresh and frozen human food, bait and animal food; canned human food, bait and animal food; and cured and reduced fish for 1971 and 1972 is given in Table 4. It can be seen that the disposition for bait and animal food is a relatively small portion of the total.

## INDUSTRY BACKGROUND

The canned and preserved fish and seafood industry, including industrial products, has been expanding steadily from the early days of drying and curing to the various technologies involved in preserving, canning, freezing, and rendering of fishery products. The characteristics of the industry have been influenced by changing market demands and fluctuating raw product availability. The total value of fishery products processed in 1972 from both

Table 4. Disposition of landings, 1971 and 1972 (1)

| Product | Average Lbs x $10^6$ | Average Percent |
|---|---|---|
| Fresh and Frozen: | | |
| Human food | 1420 | 29.3 |
| Bait and animal food | 92 | 1.9 |
| Canned: | | |
| Human food | 862 | 17.8 |
| Bait and animal food | 126 | 2.6 |
| Cured: | 74 | 1.6 |
| Reduced to meal, oil, solubles, etc.: | 2266 | 46.8 |
| TOTALS | 4840 | 100.0 |

Table 5. Value of fishery products, 1971 and 1972 (1)

| Item | Domestic landings | | Imports | | Total | |
|---|---|---|---|---|---|---|
| | 1971 | 1972 | 1971 | 1972 | 1971 | 1972 |
| | | | Million dollars | | | |
| Edible fishery products: | | | | | | |
| Finfish | 257 | 278 | 483 | 498 | 740 | 776 |
| Shellfish | 338 | 380 | 404 | 735 | 742 | 1115 |
| Industrial fishery products: | | | | | | |
| Finfish | 44 | 40 | 187 | 261 | 231 | 301 |
| Shellfish | 4 | 6 | N.A. | N.A. | 4 | 6 |
| Total: | | | | | | |
| Finfish | 301 | 318 | 670 | 759 | 971 | 1077 |
| Shellfish | 342 | 386 | 404 | 735 | 746 | 1121 |
| Total | 643 | 704 | 1074 | 1494 | 1717 | 2198 |

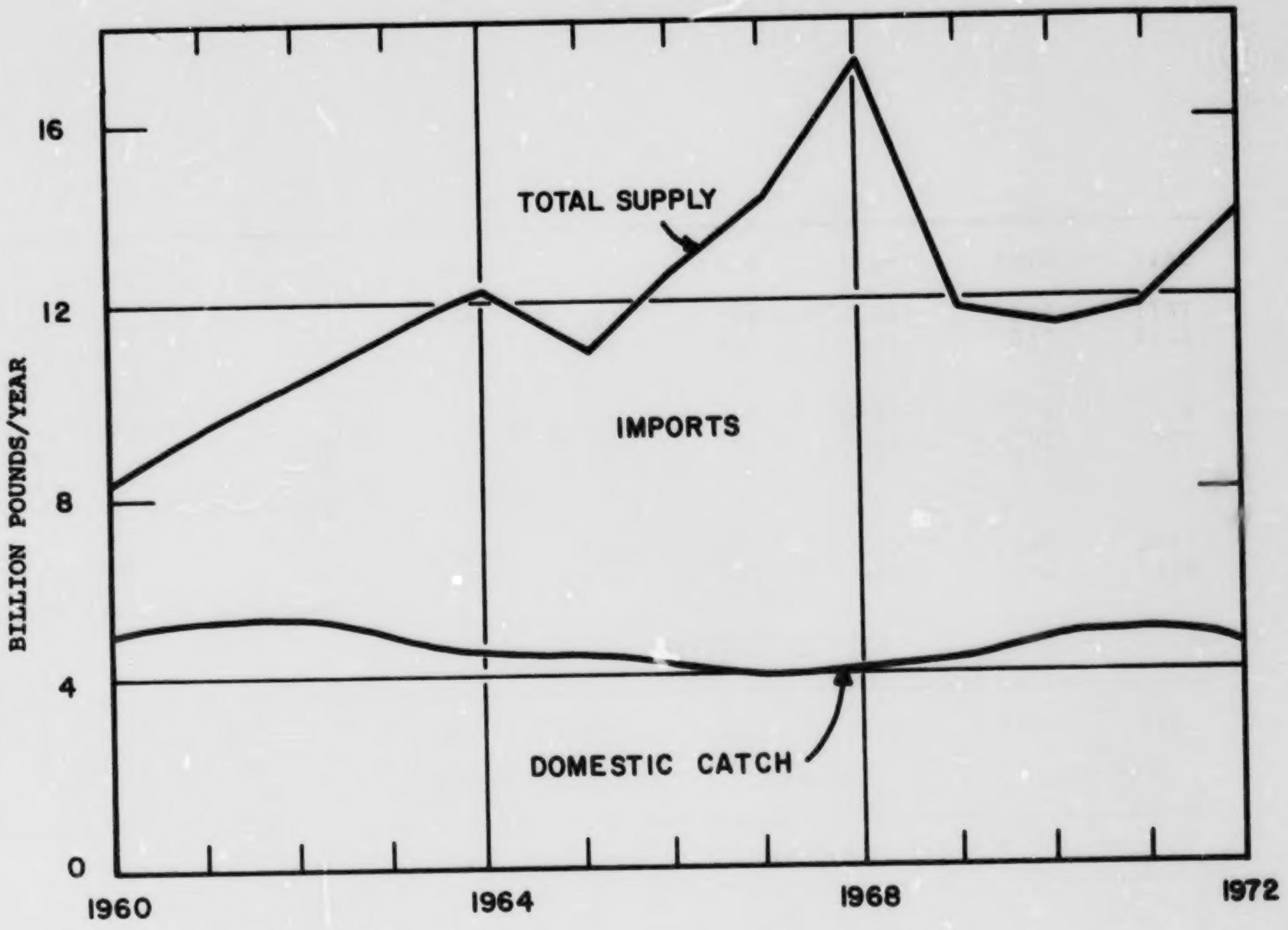
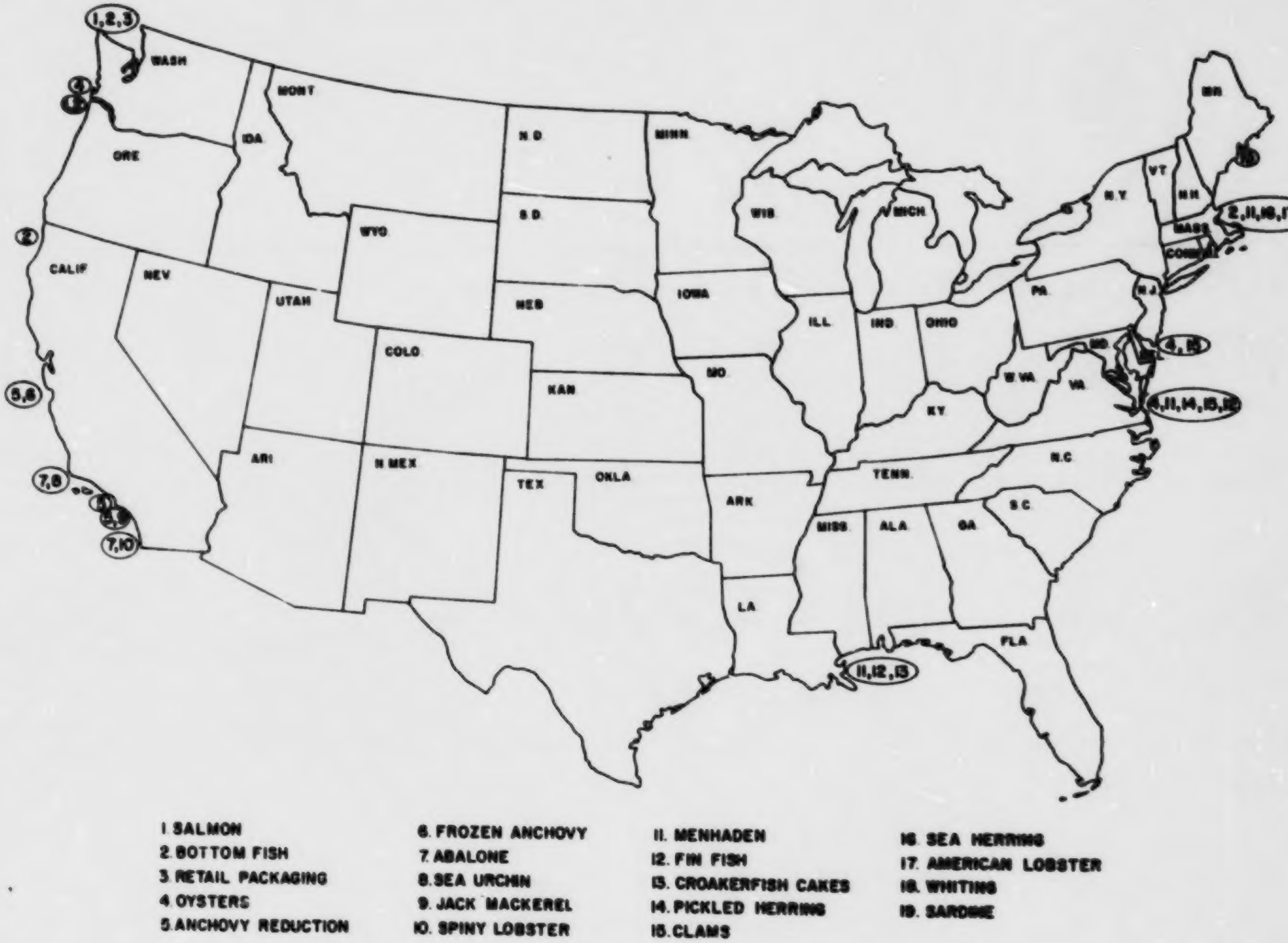


Figure 1. Total U.S. supply of fishery products, 1960-1972 (1)

Table 6. Supply of fishery products, 1971 and 1972 (1)

| Item | Domestic landings |  | Imports |  | Total |  |
|---|---|---|---|---|---|---|
|  | 1971 | 1972 | 1971 | 1972 | 1971 | 1972 |
|  | Million pounds, round weight |  |  |  |  |  |
| Edible fishery products: |  |  |  |  |  |  |
| Finfish | 1509 | 1432 | 2967 | 3751 | 4476 | 5183 |
| Shellfish | 891 | 878 | 615 | 703 | 1506 | 1581 |
| Industrial fishery products: |  |  |  |  |  |  |
| Finfish | 2545 | 2383 | 3204 | 4589 | 5749 | 6972 |
| Shellfish | 24 | 17 | N.A. | N.A. | 24 | 17 |
| Total: |  |  |  |  |  |  |
| Finfish | 4054 | 3815 | 6171 | 8340 | 10,225 | 12,155 |
| Shellfish | 915 | 895 | 615 | 703 | 1530 | 1598 |
| Total | 4969 | 4710 | 6786 | 9043 | 11,755 | 13,753 |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4
ORE
2
CALIF
5,6
7,8
7,10
IDA
MONT
NEV
UTAH
ARI
WYO
COLO
N MEX
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S D
NEB
KAN
OKLA
TEX
MINN
IOWA
MO
ARK
LA
WIS
ILL
MICH
IND
OHIO
KY
TENN
MISS
ALA
GA
FLA
11,12,13
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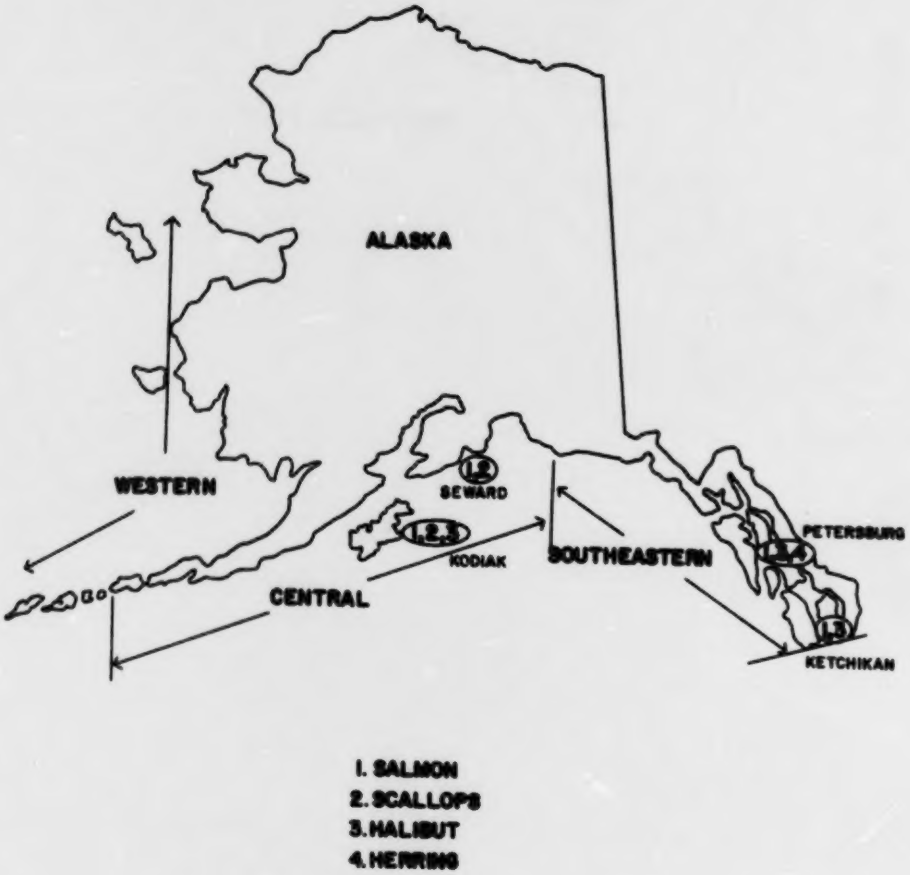
VA
W VA
MD
PA
N J
N Y
VT
N H
MASS
CONN
ME
2,11,16,17,18
4,15
4,11,14,15,19
1 SALMON
2 BOTTOM FISH
3 RETAIL PACKAGING
4 OYSTERS
5 ANCHOVY REDUCTION
6 FROZEN ANCHOVY
7 ABALONE
8 SEA URCHIN
9 JACK MACKEREL
10 SPINY LOBSTER
11 MENHADEN
12 FIN FISH
13 CROAKERFISH CAKES
14 PICKLED HERRING
15 CLAMS
16 SEA HERRING
17 AMERICAN LOBSTER
18 WHITING
19 SARDINE

Figure 2. Locations and commodities sampled in the contiguous United States.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CENTRAL
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SEWARD
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KODIAK
PETERSBURG
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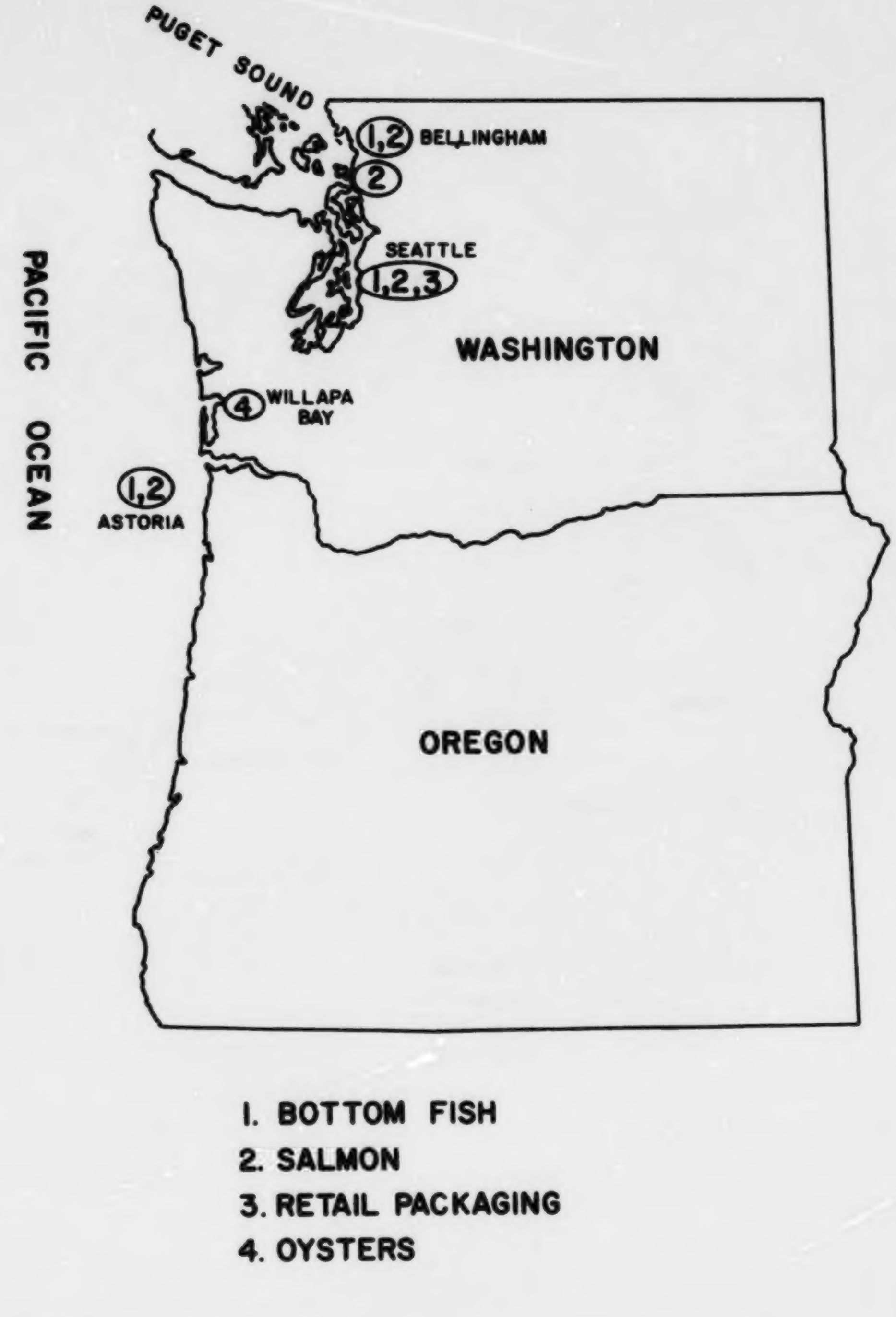
1,3
KETCHIKAN
1. SALMON
2. SCALLOPS
3. HALIBUT
4. HERRING

Figure 3. Alaska region locations and commodities sampled.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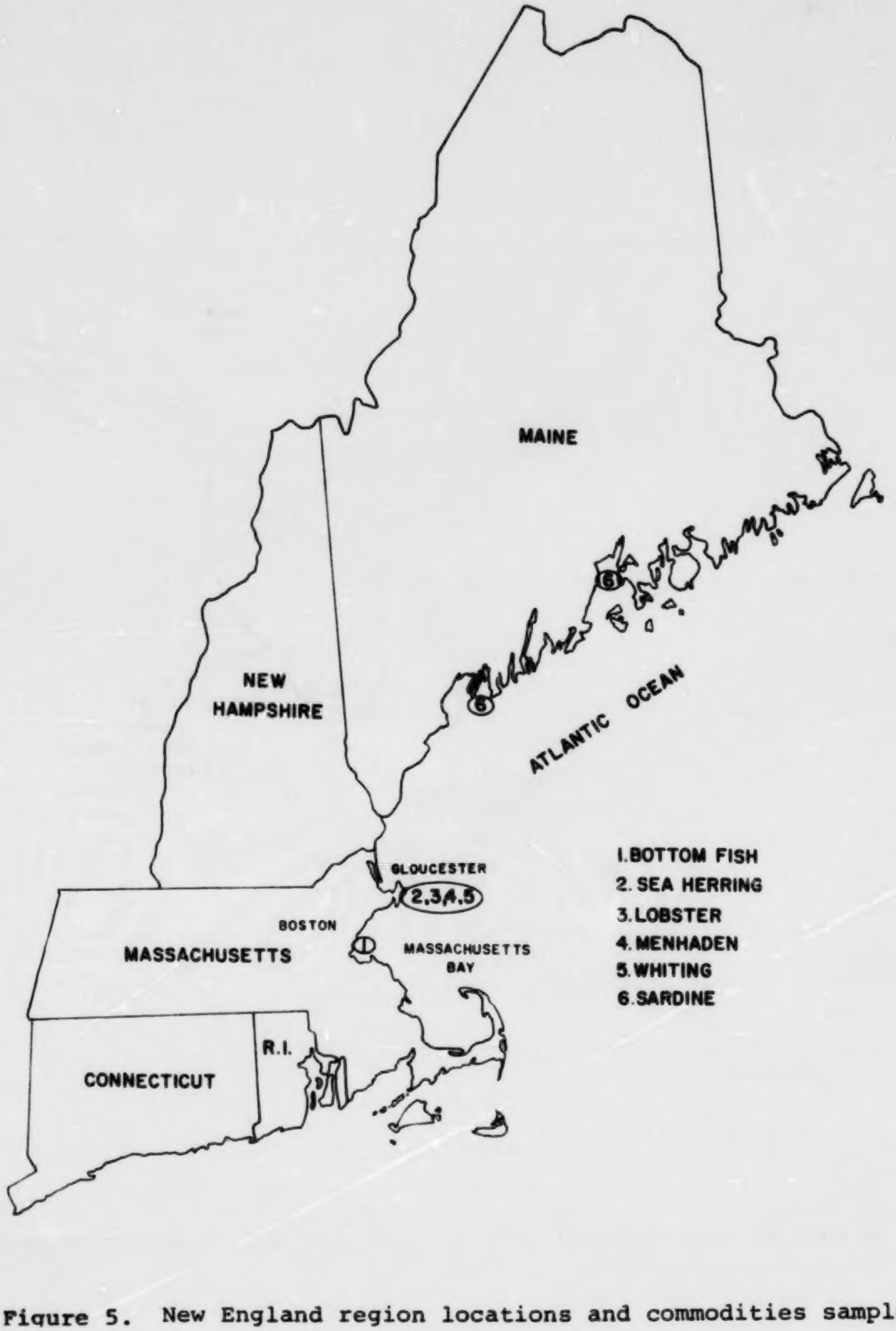
2
SEATTLE
1,2,3
WASHINGTON
4 WILLAPA BAY
1,2 ASTORIA
OREGON
1. BOTTOM FISH
2. SALMON
3. RETAIL PACKAGING
4. OYSTERS

Figure 4. Northwest region locations and commodities sampled.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MASSACHUSETTS
CONNECTICUT
R.I.
ATLANTIC OCEAN
GLOUCESTER
2,3,4,5
BOSTON
1
MASSACHUSETTS BAY
6
6
1. BOTTOM FISH
2. SEA HERRING
3. LOBSTER
4. MENHADEN
5. WHITING
6. SARDINE

Figure 5. New England region locations and commodities sampled.

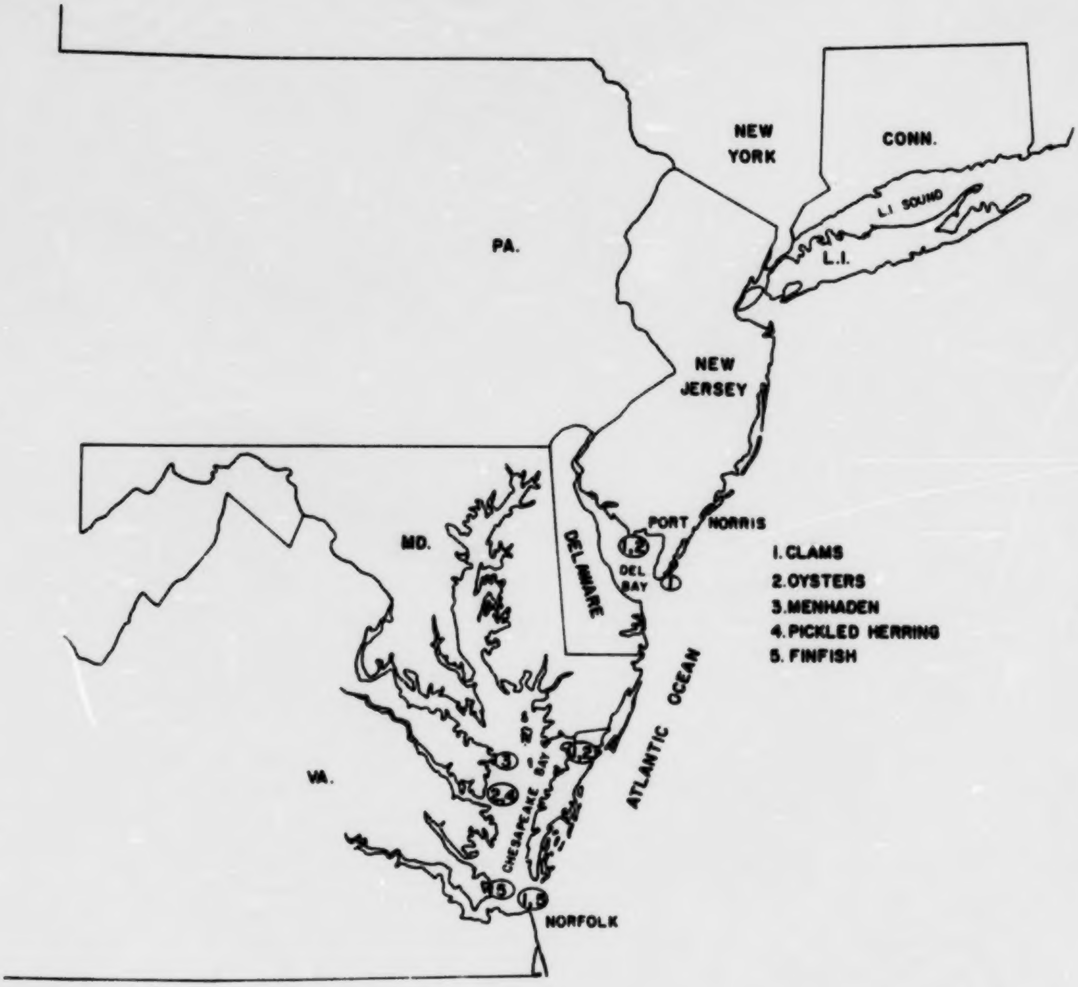
NEW YORK
CONN.
L.I. SOUND
L.I.
PA.
NEW JERSEY
PORT NORRIS
1,2
DEL BAY
1
DELAWARE
MD.
1. CLAMS
2. OYSTERS
3. MENHADEN
4. PICKLED HERRING
5. FINFISH
ATLANTIC OCEAN
VA.
3
2,4
1,2
CHESAPEAKE BAY
5
1,5
NORFOLK

Figure 6. Mid-Atlantic region locations and commodities sampled.

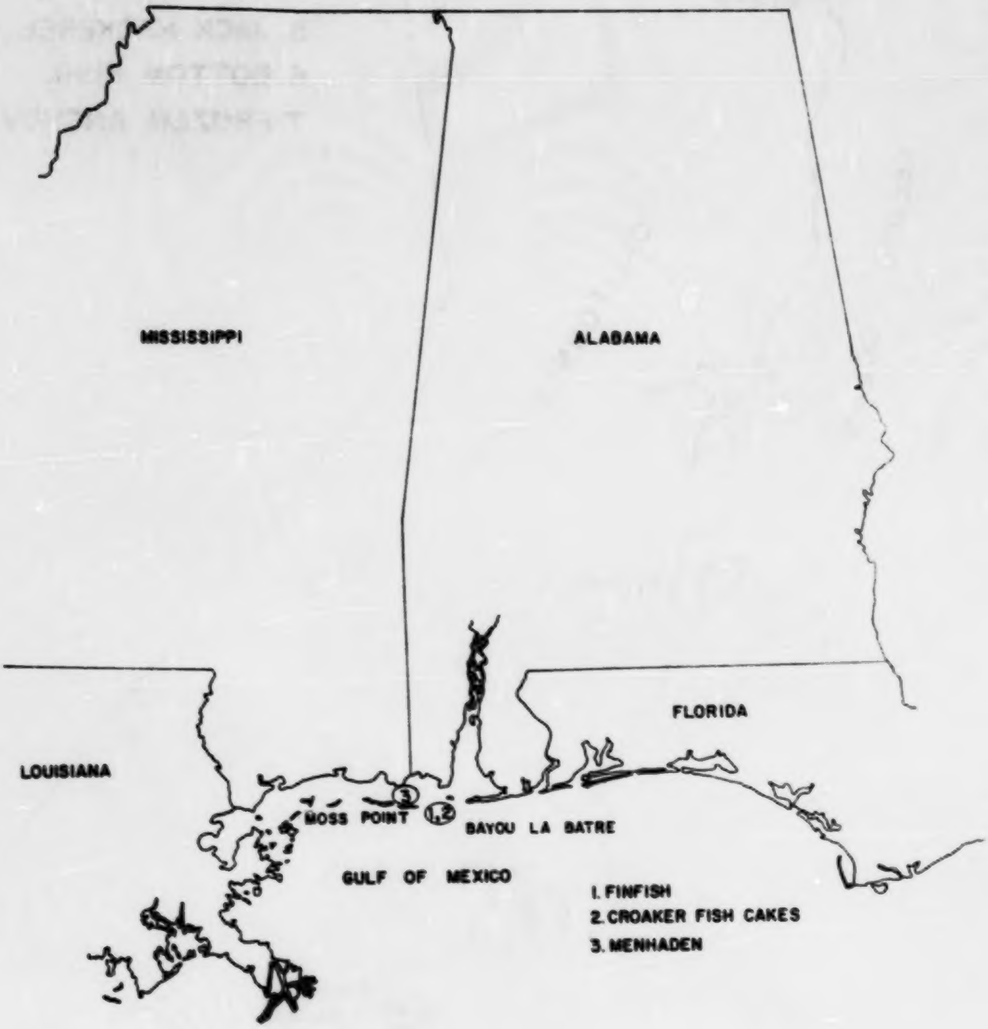
MISSISSIPPI
ALABAMA
FLORIDA
LOUISIANA
3
1,2
MOSS POINT
BAYOU LA BATRE
GULF OF MEXICO
1. FINFISH
2. CROAKER FISH CAKES
3. MENHADEN

Figure 7. Gulf region locations and commodities sampled.

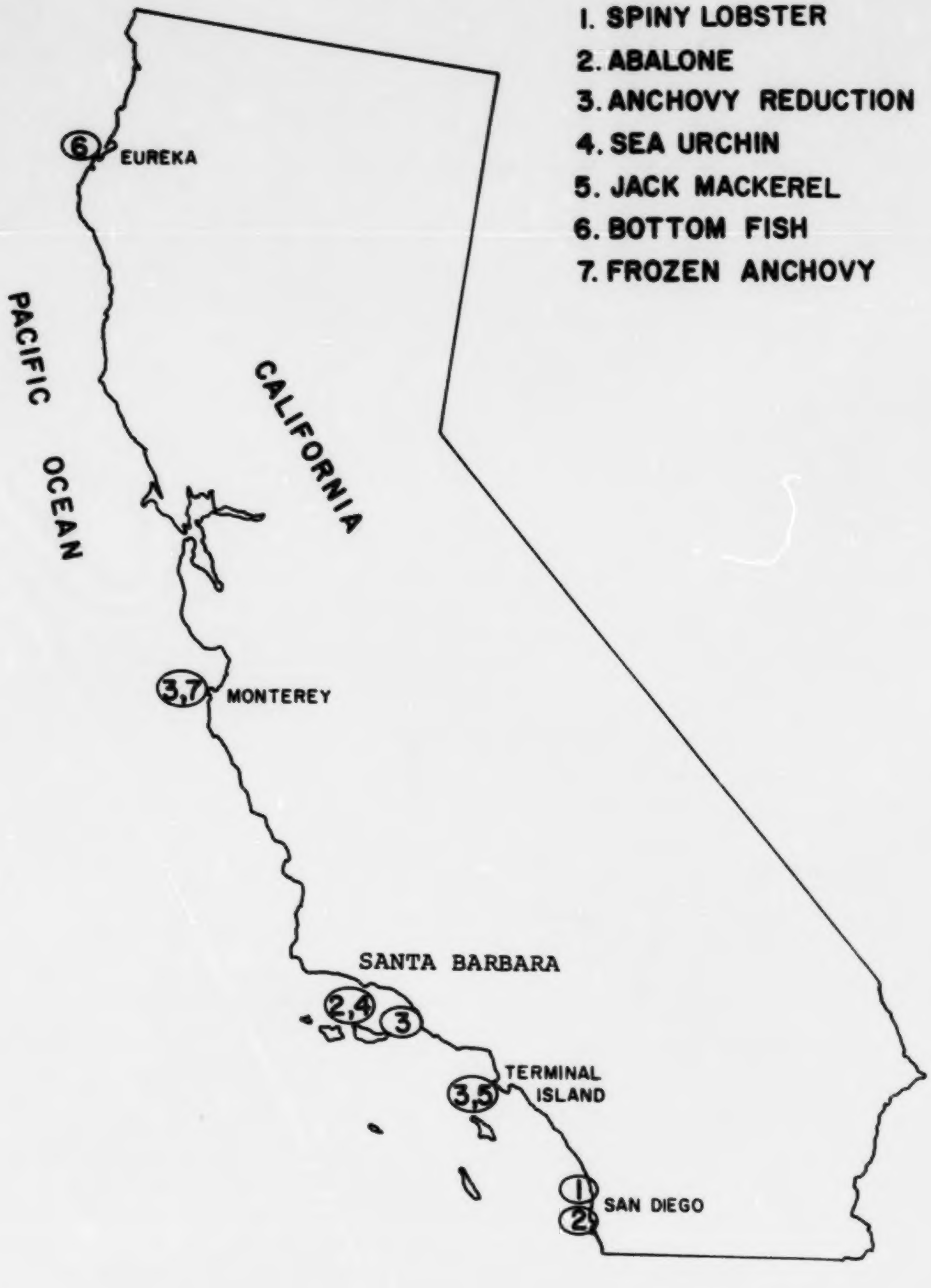
1. SPINY LOBSTER
2. ABALONE
3. ANCHOVY REDUCTION
4. SEA URCHIN
5. JACK MACKEREL
6. BOTTOM FISH
7. FROZEN ANCHOVY
PACIFIC OCEAN
CALIFORNIA
6
EUREKA
3,7
MONTEREY
SANTA BARBARA
2,4
3
3,5
TERMINAL ISLAND
1
2
SAN DIEGO

Figure 8. California region locations and commodities sampled.

Table 7. Production of industrial fishery products, 1962-1972 (1)

| Year | Quantity |  |  | Value |
|---|---|---|---|---|
|  | Fish Meal | Fish Solubles | Marine Animal Oil | Fish Meal, Oil, and Solubles |
|  | tons | tons | thousand pounds | thousand dollars |
| 1962 | 312,259 | 124,649 | 250,075 | 53,210 |
| 1963 | 255,907 | 107,402 | 185,827 | 47,842 |
| 1964 | 235,252 | 93,296 | 180,198 | 46,998 |
| 1965 | 254,051 | 94,840 | 195,440 | 56,498 |
| 1966 | 223,821 | 83,441 | 164,045 | 49,916 |
| 1967 | 211,189 | 74,675 | 122,398 | 36,738 |
| 1968 | 235,136 | 71,833 | 174,072 | 41,294 |
| 1969 | 252,664 | 81,692 | 169,785 | 53,272 |
| 1970 | 269,197 | 94,968 | 206,084 | 69,485 |
| 1971 | 292,812 | 111,188 | 265,450 | 70,377 |
| 1972 | 285,486 | 134,404 | 188,445 | 67,371 |

Table 8. Atlantic menhaden fishing seasons.

| Area | Earliest Date | Peak Months | Latest Date |
|---|---|---|---|
| North | May 25 | July-August | October 20 |
| Middle | May 16 | July-September | November 19 |
| South | March 23 | June | December |

domestic and imported raw materials was a record $2.3 billion, 23 percent above the previous record reached in 1971 (Table 5). In addition to the value of these processed products, the total supply of fishery products increased in 1972, largely due to greater imports (Figure 1 and Table 6). The per capita U.S. consumption of fish and shellfish in 1972 was 5.5 kg (12.2 lbs) totaling 1.14 million kkg (1.25 million tons), up seven percent from 1971 (1).

The seafood industry considered in this study was organized into three general segments: industrial fishes, finfishes, and shellfishes. General background material such as: species involved, volumes, values and locations of landings, and methods of harvesting and handling are discussed in this section. A more detailed discussion of specific processes and wastes generated will be found in Sections IV and V, which deal with industry categorization and waste characterization, respectively.

Monitoring of individual processors included four months of intensive study of the major seafood processing and fish rendering centers in the contiguous United States and Alaska. The general sampling locations are identified in Figures 2 and 3. Selection of representative plants was based on several factors, including: size, age, level of technology, and geographic location. For the purpose of organizing the sampling effort, the country was divided into seven regions: Alaska, Northwest, Great Lakes, New England, Middle Atlantic, South Atlantic and Gulf, and California. Maps of each region, excluding the Great Lakes, showing the location of the plants monitored during this study and the types of fish or shellfish commodities sampled are in Figures 3 through 8. The Great Lakes region was not sampled because of a lack of fish processing activity.

## INDUSTRIAL FISHES

Industrial fishery products include such commodities as fish meal, concentrated protein solubles, oils, and also miscellaneous products including liquid fertilizer, fish feed pellets, kelp products, shell novelties and pearl essence.

Only that portion of this industry, the reduction of anchovy and menhaden, involving rendering fish to meal, oil and solubles was specifically studied. The use of herring for meal is declining because of the decline of the resource and because of its greater utilization for direct human consumption. The use of alewives for meal has been declining in recent years; however, the utilization of this species may increase as demand increases and the world supply of fish meal decreases. Table 7 shows the volume and value of the meal, oil, and solubles products for the last ten years. The value for 1973 is expected to have increased dramatically due to the current fish meal shortage.

With respect to the rendering of fish to meal, solubles, and oils, the two most common species harvested for this purpose are the Atlantic menhaden and the Pacific anchovy. These fishes and the attendant reduction industry were considered to be important from a pollution impact viewpoint and were studied relatively thoroughly.

## Menhaden

Menhaden are small oily fish belonging to the herring family, Clupeidae, and members of the genus Brevoortia. Of this genus only two species are important to the menhaden fishery. On the Atlantic Coast B. tyrannus dominates, while on the Gulf Coast B. patronus is more important. The fish are generally 12 inches in length and weigh less than a pound. They are found migrating in schools of 50,000 to 200,000 along the Atlantic and Gulf Coasts.

Menhaden utilization in the United States preceeded the landing of the pilgrims. The East Coast Indians planted corn along with a fish called munnawhatteaug (menhaden) as a fertilizer. They passed this technique on to the early settlers. The early 1800's saw the organization of a number of small companies to supply manhaden for fertilizer. In the 1850's the first large-scale reduction plants appeared on the New England Coast, and since then the fishery has grown to a multi-million dollar industry. Landings totaled 863,000 kkg (1.94 billion lbs) for 1972, comprising 41 percent of the total U.S. landings for that year. Fifty-seven percent of the landings were from the Gulf of Mexico with the balance from the Atlantic Coast (1).

Landing statistics from 1950 to 1956 show that catches from the Atlantic increased from 318,000 kkg (0.700 billion lbs) to 699,000 kkg (1.54 billion lbs), comprising 73 percent of the catch in 1956, and since then have shown a general decline. The Gulf fishery, on the other hand, has been increasing, and first exceeded the Atlantic in 1963, when 440,000 kkg (0.968 billion lbs) were landed. The Gulf fisheries have held their lead over the Atlantic consistently since 1963 (Figure 9) (1).

Both Atlantic and Gulf menhaden are caught with purse seine nets, the principal gear utilized by the industry since 1850. The menhaden seine is 400 to 600 m (1312 to 1969 ft) long, 25 to 30 m (82 to 98 ft) deep with 3 to 6 cm (1.2 to 2.4 in.) mesh. A typical operation consists of two smaller seine boats which accompany a carrier vessel 20 to 60 m (197 ft) in length and which has a hold capacity ranging from 45 to 544 kkg (50 to 600 tons). Fishing generally takes place during the day within 60 km (37 mi) of the reduction plant. A small plane is used to spot concentrations of fish and direct the carrier boats to them. At the fishing site a suitable school of menhaden is selected and the seine boats dispatched. The boats separate at the school and each plays out its half of the net until the fish are enclosed. The net is then joined and its perimeter reduced to concentrate the fish. The carrier vessel comes alongside the net and pumps the catch aboard. The catch is generally delivered to the reduction plant within one day of landing. The holds of some vessels are refrigerated, allowing the carrier to remain at sea for longer periods.

The fishing season in the Atlantic runs from April to December. Table 8 lists the typical seasons for the North, Middle and South Atlantic.

The fishing season on the Gulf Coast runs from May to October with peak months in July and August (2).

Ninety-nine percent of the menhaden landed in the U.S. are reduced for fish meal, oil, and fish solubles. The fish meal is primarily utilized as a protein supplement in animal feeds. That oil which is exported is used in shortening and margarine, domestically it is used in protective coatings, lubricants, medicinals, cosmetics and some soaps. A limited market exists for fish solubles as a liquid fertilizer. They are also combined with fish meal for use as animal feed.

Meal, oil, and solubles are extracted from the fish via a wet reduction process. This process consists of cooking the fish with live steam at about 240°F. The cooked fish are then pressed, separating the fish into press cake (solids) and press liquor (liquid). The press cake is dryed, ground, and sold as fish meal. The press liquor is clarified and the oil is separated. The oil is then further refined, stored and shipped. The de-oiled press liquor, known as stickwater, is usually evaporated to about 50 percent solids and sold as fish solubles.

## Anchovy

The northern anchovy (Engraulis mordax) is a small pelagic fish, averaging six inches in length at maturity, which is found in large schools off the west coast of North America. Feeding on plankton as well as small fish, the anchovy is a direct competitor with the Pacific sardine throughout its range (3). Coincident with the failure of the sardine fishery, the anchovy fishery has exhibited a dramatic increase in the last 15 years, as shown in Figure 10.

During the summer and fall large schools of anchovy, which remain in deeper water during the daylight hours, disperse to the surface in the evening and re-form into dense schools until dawn when they again submerge. This behavior pattern allows the use of purse seines in the early morning. The harvesting methods are much like those used for menhaden and the catch is usually delivered to the processor on the same day it is harvested.

The anchovy is utilized for canning, reduction and live bait; sportsmen use more than 4500 kkg (5000 tons) yearly as bait. Because of economic conditions and (presumably) low consumer

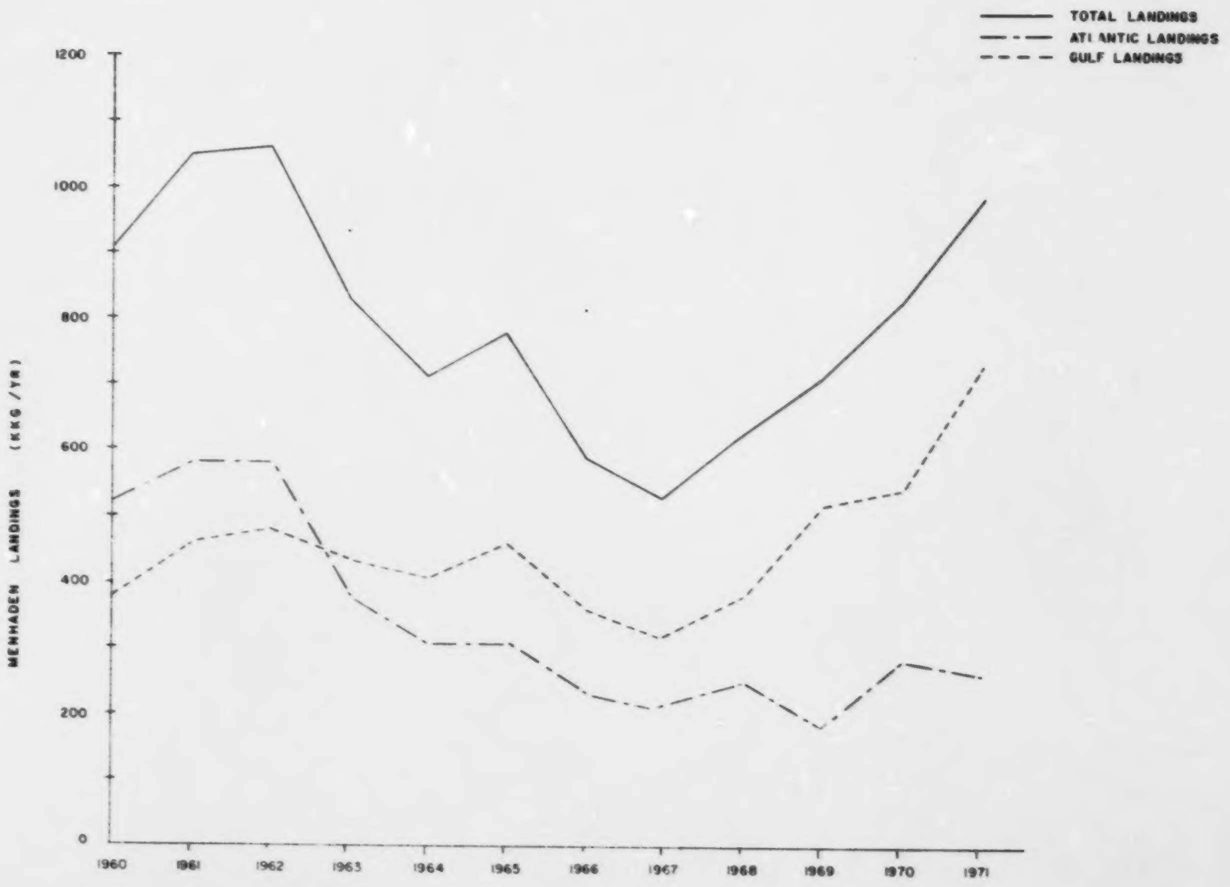

Figure 9. Atlantic and Gulf menhaden landings, 1960-1971 (1)

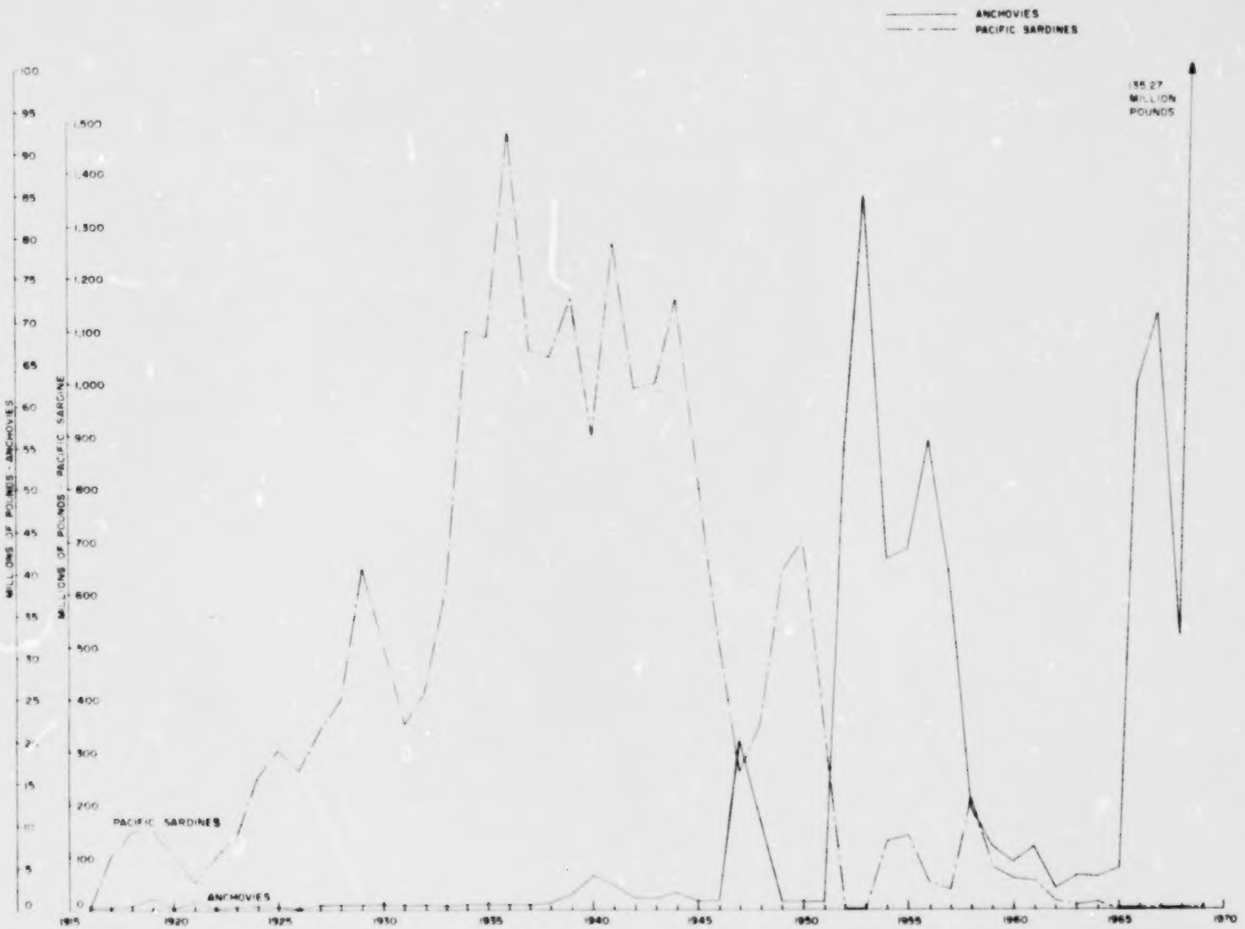

Figure 10. California landings of Pacific sardines and anchovies (3)

acceptance of the canned product, landings declined to 17,600 kkg (19,400 tons) in 1957 and 4720 kkg (5200 tons) in 1958 (3). Landings did not again exceed 4500 kkg (5000 tons) until 1966 when, for the first time in over 40 years, anchovy were fished mainly for reduction purposes (4). The major portion of the anchovy harvest is now utilized by the reduction industry. The season quota for the industry is currently 104,000 kkg (115,000 tons) (1).

The total adult biomass of anchovy has been estimated to be 4.1 to 5.1 million kkg (4.5 to 5.6 million tons), 50 percent of which resides off California (4). The 1972 harvest of anchovy was 67,678 kkg (74,535 tons), up 41 percent from 1971 (1). Preliminary figures indicate the catch for 1973 was higher than previous years (1).

Once caught, the anchovy are stored in the boat holds, until they are pumped directly into the plant. Reduction of anchovy to fish meal, oil and solids is essentially the same process as that employed using menhaden.

## FINFISH

The term "finfish" is used in this section to refer to those fishes (excluding shellfishes) which are processed for human consumption. Included are pelagic species such as salmon, herring, ocean perch, mackerel, etc.; and benthic species such as halibut, flounder, cod, sole, etc. Finfish landings in 1972 totaled 650 million kg (1432 million lbs), which represented about 30 percent of the total landings for that year (1).

As changes in species availability, consumer demand, and food technology occur, the quantities of various types of fishes harvested and the methods of processing vary considerably. Over the years the industry has shifted emphasis from salting, drying, smoking, and pickling to freezing and canning as methods of preservation. In most cases the fish are prepared by evisceration, then reduction to fillets or sections, and subsequently application of preservation technology. Each of the various finfish processing industries considered during this study are introduced below; a more detailed process description for each appears in Section IV.

### Salmon

One of the most important finfish processing segments covered was the preservation of salmon by canning and freezing.

The first salmon cannery was located on the Sacramento River in California and produced 2000 cases in 1864. Soon canneries appeared along most major river systems of the West Coast. Local regulation of the fishery began in 1866. However, growing urbanization and resultant pressure on the salmon spawning runs has significantly reduced the number of plants along the West Coast. The largest segment of the fishery is now centered in Alaska.

Five species of Pacific salmon are harvested in Alaska, Oregon and Washington. This harvest comprised 8.4 percent of the total United States landings and 16.1 percent of the relative value in 1972 (1). Eighty-six percent of the salmon harvested in 1972 were caught in Alaska and were processed by 43 plants. Figure 11 shows the Alaska salmon catch by species for the past 15 years. Most of the remaining 14 percent of the salmon harvest was landed in Oregon and Washington, and processed by 20 plants. The 1972 Pacific salmon pack of 98,400 kkg (217 million lbs), down 43,300 kkg (95.4 million lbs) from 1971, was one of the poorest years on record. The 1973 season in Alaska was less productive than the 1972 season; the 1973 Puget Sound season was also unimpressive.

Processing plants in Alaska are typically located in isolated areas or in small towns. Centers of production in Alaska include Dillingham, Naknek, Chignik, Kodiak, Seward, Petersburg, Wrangell and Ketchikan. Most salmon processing in Washington takes place in the Puget Sound area, and, in Oregon, around the mouth of the Columbia River.

The salmon are most often frozen and canned; relatively few are sold on the fresh market. There recently has been a trend toward an increase in the volume of frozen salmon and a decrease in canned salmon. The 1972 canned salmon pack is described by area and species in Table 9.

Because of short seasons (Table 10) and the large numbers of fish to be processed, the plants in Alaska are typically larger and operate longer hours than plants in Washington and Oregon. Season peaks in Oregon and Washington are not as well defined as those in Alaska; good fishing is available for longer periods of time. Alaska salmon canning plants were observed to contain as many as five lines (individual canning lines) and process "around the clock" if enough fish were being caught. The freezing operations were also often observed to be processing 24 hours per day in Alaska.

Severe winters, foreign fishing pressure and "off" years have greatly reduced the recent Bristol Bay red, (also called sockeye or blue back) salmon (Oncorhynchus nerka) runs. These fish populations typically fluctuate on a five-year cycle. The largest portion of the 1970 red salmon catch was harvested in Bristol Bay with the main center of processing located at Naknek. The red salmon average 2.3 kg to 3.2 kg (five to seven lbs) at maturity. The last "peak" year occurred in 1970, when over 68,100 kkg (150 million lbs) were harvested. Only 22,200 kkg (49 million lbs) were harvested in the U.S. in 1972. In addition to Bristol Bay, other areas with good sockeye runs are Chignik, Copper River, Fraser River (British Columbia) and the rivers

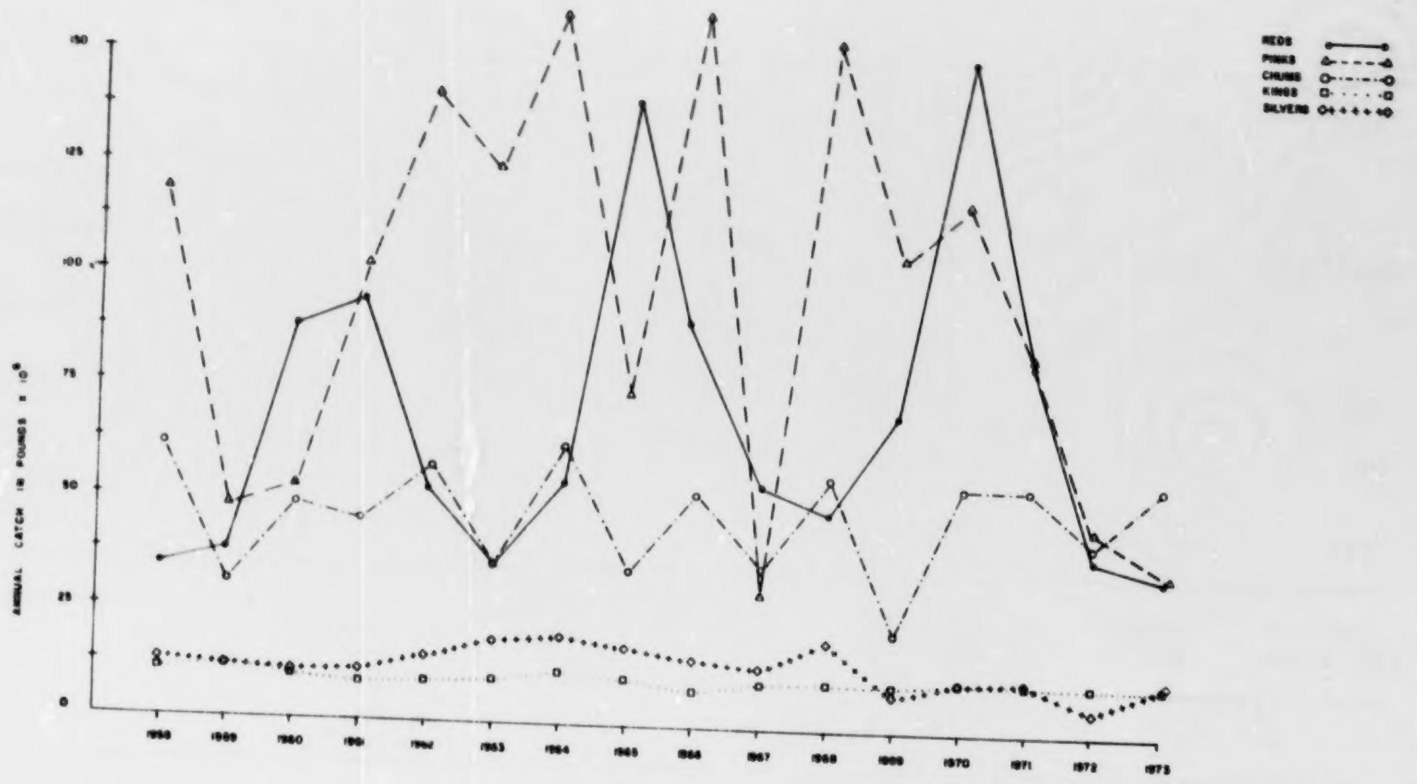

Figure 11. Alaska salmon landings by species (1)

Table 9. 1972 Pacific canned salmon packs and values (1)

| Species | Alaska | | Washington | | Oregon | |
|---|---|---|---|---|---|---|
| | Cases x 1000 | Value ($) x 1000 | Cases x 1000 | Value ($) x 1000 | Cases x 1000 | Value ($) x 1000 |
| Red or sockeye | 519.9 | 35,013 | 107.6 | 7,894 | 4.7 | 351 |
| Pink | 610.8 | 28,008 | 12.8 | 580 | 0.4 | 38 |
| Chum | 473 | 18,761 | 52.8 | 2,113 | 1.0 | 42 |
| Silver or coho | 50.4 | 2,566 | 9.5 | 944 | 7.3 | 274 |
| King or chinook & steelhead* | 13.2 | 652 | 7.6 | 393 | 21.1 | 1,229 |
| TOTAL | 1,667.3 | 85,000 | 190.3 | 11,924 | 34.5 | 1,934 |

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* Note that the steelhead is not truly a salmon; rather it is an anadramous rainbow trout.

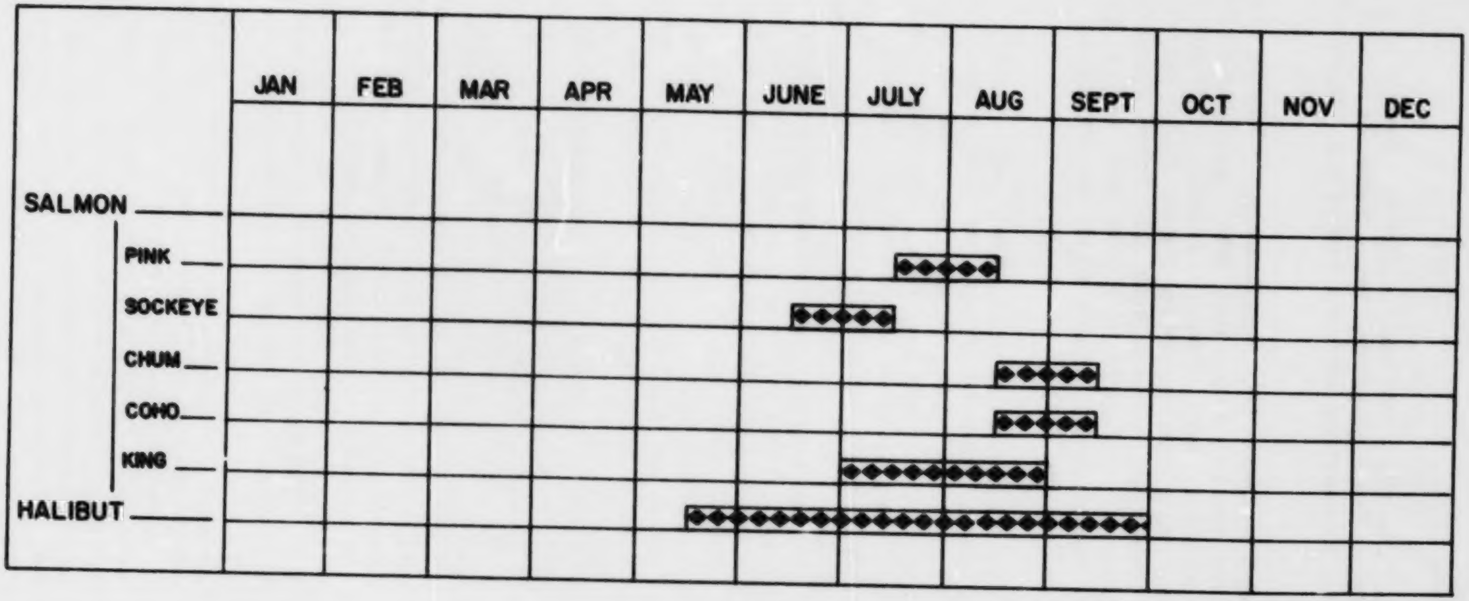


Table 10. Processing season peaks for Alaska salmon and halibut (6)(7)

flowing into Puget Sound. The red salmon cycle in the Fraser River is typically a four year cycle. Many Fraser River fish are harvested by U.S. fishermen before entering Canadian territorial waters.

Pink, or humpbacked salmon (O. gorbuscha) range from Northern California to the Bering Sea, but most are harvested in Central and Southeastern Alaska and Puget Sound. These salmon peak typically on a two-year cycle, with large runs occurring in even-numbered years. However, some areas may have runs of equal sizes in successive years. In 1972, 22,200 kkg (48.8 million lbs) of this species were harvested. Each fish at maturity weighs 1.4 kg to 2.3 kg (three to five lbs).

Caught incidentally along with the red and pink salmon, over 18,600 kkg (41 million lbs) of chum, or dog salmon (O. keta) were harvested in 1972. This fish, like the pink salmon, ranges from Northern California to the Bering Sea. Special late seasons for gill netting the dog salmon are held in Alaska. Their average weight is 2.7 kg to 3.6 kg (six to eight lbs). Coho, or silver salmon (O. kisutch) and the king, or chinook salmon (O. tschawytscha) are caught mainly in Southeastern Alaska and along the Oregon and Washington coasts. A well-known king salmon run also occurs at Dillingham in Bristol Bay. The coho salmon caught in 1972 totaled 2400 kkg (5.3 million lbs) and the kings harvested weighed 1500 kkg (3.2 million lbs). King salmon average 5.4 kg to 11.4 kg (12 to 25 lbs), while coho salmon range from 2.7 to 4.1 kg (six to nine lbs) at maturity.

Regulation of the salmon fishery is accomplished by employing quotas (limiting the catch) and limitations on vessel and equipment size and efficiency. Seasons in Bristol Bay are generally set on a day-to-day basis with closures in peak years occurring when the daily capacity of the canneries is reached. In "off" years, closures are enforced when escapement is not adequate to sustain the population. Central and Southeastern Alaska seasons are set on a weekly basis. The Puget Sound red salmon fishery is regulated by a bilateral commission involving the United States and Canada, since many of the fish come from the Fraser River in British Columbia. Seasons are set to provide proper escapement levels in the other areas of Oregon and Washington, too.

Salmon are harvested primarily by three different methods: trolling, purse seining and gill netting. Trolling involves four to eight weighted lines fished at various depths. One or two men handle the relatively small boats. Both artificial lures and natural bait are used. Troll harvested fish are dressed and iced as soon as they are caught, allowing a boat to be at sea seven to ten days at a time. Salmon caught in this manner are usually frozen, but may be canned. High prices are paid for fish caught in this manner, making trolling economically attractive. Coho and king salmon are most often caught by the trolling method.

The purse seine is a very effective harvesting method when fish can be found congregated or schooled. The net is laid in a circle with one end attached to the power skiff. Once the circle is closed, the net is pursed at the bottom to prevent fish from escaping. The net is retrieved by passing it through a power block. Once the salmon are in a sufficiently small area, they are bailed onto the boat. This type of net is used effectively in Central and Southeastern Alaska, and in the Puget Sound area.

The last method, gill netting, can be fished from boats (drift gill netting) or from shore (set gill netting). Both types catch the fish by entanglement; nets are usually set across migration routes. The nets are periodically "picked" so the fish can be taken to the processing plant. This method is used primarily in Bristol Bay.

A limited number of fish are also taken by Indians using traps and fish wheels. These harvesting methods are illegal for all but native fishermen.

Larger vessels, called tenders, usually bring the salmon from the fishing grounds to the processing plant. Fishing boats coming into the plant because of breakdowns and supply shortages also deliver fish to the plant. It is more common for trollers to deliver directly to the plant than seiners and gill netters. Tenders using chilled brine can store the fish up to four days without freezing. Dry tenders, which are rapidly becoming obsolete, must return to the processing plants daily. A few tenders ice their fish.

The salmon are unloaded from the vessels by means of either air/vacuum, elevator, or bucket systems, conveyed into the plant and sorted by species into holding bins. Salmon to be canned are usually put through a butchering machine which removes the head, tail, fins, and viscera; manual butchering is still practiced in some plants. The cleaned salmon are inspected and conveyed to filling machines equipped with gang knives which cut the salmon into appropriate sized sections designed to fit the various sized cans. The filled cans, which may be handpacked in some plants, are then seamed and retorted. Other products, such as eggs and milt, are retained for human consumption; heads, fins, and viscera are either discharged or rendered into oil and meal.

Salmon to be frozen are beheaded and manually eviscerated before a final cleaning in a rinse tank. Troll-caught fish are cleaned at sea and need only beheading and rinsing. The fish are then quick-frozen in blast or plate freezers at approximately -34°C (-29°F). After glazing (covering of the fish with ice or a polymer solution), which protects them from dehydration, the fish are stored until export. Most frozen salmon are exported to Japan and Europe.

## Bottom Fish

"Bottom fish," for the purpose of this report, refers to several species of Atlantic, Gulf, or Pacific food fishes. The types of fish included vary according to the geographic area and the harvesting method employed. Also, depending on the locality, different generic names are applied to these kinds of fishes. The term "bottom fish" is used primarily on the West Coast. The term "finfish" usually refers to those species of fish which are caught together, are predominantly pelagic varieties, and are primarily handled by plants located in the Middle, Southern Atlantic and Gulf Coast regions. "Ground fish" refers to varieties of fish that inhabit the North Atlantic region.

Bottom fish are ordinarily limited to the continental shelf, living on or near the ocean bottom. On the East Coast the shelf may extend (in places), over 200 miles, while the West Coast is characterized by a narrower shelf extending about ten miles. These continental shelves provide a rich environment for the proliferation of this fishery resource. United States landings of classified species of bottom fish were 238,000 kkg (525 million lbs) in 1972, which represents 35 percent of the total landings of edible finfish for that year.

Individual plants may utilize both mechanical and conventional means to prepare fish portions or whole fish for market. The majority of the fish is frozen while the remainder is marketed fresh.

With respect to the bottom fish found off the Atlantic and Gulf Coasts, more than 40 different species are harvested. Table 11 lists the species which constitute the majority of the landings.

The fishing season is open all year, with the peak occurring during the summer months. Because of the infringement of foreign fishing vessels, the ground fish industry in the North Atlantic is decreasing in size. However, recent legislative action has been aimed at re-defining the limits of these rich fishing grounds, and hopefully will result in an equitable distribution of the catch among the various countries.

The Pacific Coast bottom fishery appears to be a relatively stable industry at present. The current limits on the growth of the industry are determined mainly by fishing conditions and market demand. The peak season usually occurs during the summer months; however, for most species, the season is continuous. Table 12 lists average landings of the major Pacific bottom fish species. Market demand is affected by consumer preference, special seasons, and labor availability. Future expansion of the industry will probably be dependent on an increased demand for such products as fish protein concentrate or fish flesh.

Ground fish in the North Atlantic and bottom fish on the Northwest Coast are harvested primarily by large trawlers. A trawler is a boat equipped with a submersible net, termed an otter trawl, which is dragged behind the boat at various depths

Table 11. Major species of Atlantic and Gulf bottom fish (1)

| Species | Landings 1967-1971 average (kkg) |
|---|---|
| Flounder: | |
| yellowtail (*Limanda ferruginea*) | 30,267 |
| blackback (*Psuedopleuronectes americanus*) | 10,438 |
| other | 4673 |
| Ocean perch (*Sebastes marinus*) | 27,545 |
| Whiting (*Marluccius bilinearis*) | 24,646 |
| Haddock (*Melanogrammus aeglefinus*) | 23,892 |
| Cod (*Gadus morhua*) | 23,325 |
| Mullet (*Musel cephalus*) | 14,482 |
| Seatrout: | |
| gray (*Cynoscion regalis*) | 2811 |
| other (*Cynoscion spp.*) | 3230 |
| Pollock (*Pollachius virens*) | 4036 |
| Croaker (*Micropogon undulatus*) | 3126 |

Table 12. Major species of Pacific bottom fish (1)

| Species | Landings 1967-1971 average (kkg) |
|---|---|
| Flounders (numerous species) | 20,697 |
| Rockfishes (numerous *Sebastes* species) | 12,047 |
| Ocean perch (*Sebastes alutus*) | 6194 |
| Hake (*Merluccius productus*) | 6030 |
| Red Snapper (*Sebastes rubirrimus*) | 4811 |
| Cod (*Gadus macrocephalus*) | 2560 |

depending on the types of fish pursued. The mouth of the net is kept open by a cork line on top, a lead line on the bottom, and "doors" (metal or wood planning surfaces) on the sides. The fish are swept into the mouth of the net and accumulate in the heavily reinforced rear portion, the cod end.

The smaller "finfish" fishery on the South Atlantic Coast and Gulf Coast is harvested by various methods, depending on locality. The otter trawl is the major method used in the Gulf. Haul netting and pound netting are two methods regularly used along the mid-Atlantic Coast; the third method is gill netting. Haul netting is a form of beach seining in which a long net is anchored to the shore, pulled out to sea, then circled around and brought back into the beach. The area impounded by the net is then shrunk by pulling the net onto the beach, and the trapped fish are collected. The second method, "pound netting," involves stringing a net perpendicularly to the shore and creating a circular impoundment at the offshore end of the net. As the fish swim into the net, they tend to follow it seaward until they reach the impoundment, in which they are trapped.

Bottom fish processing primarily involves the preparation of filleted portions for the fresh or frozen market. Whole fish and fish cakes may also be prepared depending on the region and kind of fish processed. The fish are delivered to the docks and, if not previously done on the vessel, are sorted according to species. Fish to be filleted are passed through a pre-rinse and transported to the fillet tables where skilled workers cut away the two fleshy sides. These portions are then either mechanically or manually skinned prior to packaging. Whole fish are run through a descaling machine, or may be descaled by hand, and eviscerated. Most whole fish go directly to the fresh market.

A relatively new process within the United States, utilizes recently-developed flesh separating machinery to extract flesh from fish. Frozen cakes and blocks are the end products. Although new, the process holds much promise because it can attain high yields, utilize previously ignored fish species, and serve large markets. The foundation for this process was laid when Japanese and German inventors created the prototype machinery for extracting flesh from eviscerated fish without incorporating bone and skin into the finished product. The method of operation essentially is a shearing and pressing action created by a rotating perforated drum bearing against a slower moving belt that holds the fish tightly against the drum.

### Halibut

Two species of halibut are harvested in the United States. The Atlantic halibut (Hippoglossus hippoglossus), which is harvested off the Northeast Coast, comprised less than one percent of the total halibut catch in 1972. The Pacific halibut (Hippoglossus stenolepis) is harvested from Northern California to Nome, Alaska (Figure 12). Alaska and Washington accounted for 69 and 31 percent, respectively, of the West Coast harvest in 1969. Processing plants in Alaska are typically located in small towns such as Sand Point, Kodiak, Seward, Juneau, Pelican, Sitka, Petersburg and Ketchikan. The centers of production in Washington are Bellingham and Seattle.

The halibut fishery was first conducted over the entire year, with most of the catch occurring between March and October. Season closures and catch limits were instituted in the early 1930's when the stocks became severely depleted. The Pacific halibut fishery is now regulated by the International Pacific Halibut Commission (IPHC) to which the United States, Canada, and Japan belong. It is the IPHC that does most research on and regulation of the fishery. The harvest of the halibut in the United States has been dropping in recent years (Figure 13) and the 1974 halibut quota may be less than 30 million pounds for both the United States and Canada combined (5). IPHC figures estimate the 1970 annual loss to Canadian and American fishermen at 3400 kkg (7.5 million lbs). Japan and Russia harvested most of their halibut while trawling for ocean perch and shrimp. As a member of the Commission, Japan is supposed to return the caught halibut to the ocean, but survival of these fish is poor (6).

Halibut fishing is effected with "longlines," which are composed of numerous smaller units, called "skates," that are approximately 457 m (1500 ft) long. Hooks and smaller lines called "beckets" are attached to the skate at intervals ranging between 4.0 m (13 ft) to 7.9 m (26 ft). The hooks are baited with a variety of fish including salmon heads and tails, herring, and octopus. The longlines (sometimes several miles in length) are usually fished at depths of 82 m (270 ft) to 274 m (900 ft) from four to 30 hours. Anchors are used to keep the longlines in place and flags are used to mark the ends of the lines.

Once the halibut are brought on board the boat, they are immediately butchered and iced. Some halibut are beheaded, others are not. Depending on vessel size, 4.5 kkg (5 tons) to 36.3 kkg (40 tons) of crushed or powdered ice is used on each trip. The average length of a trip in Southeastern Alaska is 13 days, whereas 20 to 25 days is common in the Alaskan Gulf (8).

After delivery to the processing plant the halibut may be either frozen whole or reduced to skinned, boneless meat sections known as "fletches." Upon receipt at the docks, the fish are beheaded, if they haven't been previously, the coelom flushed of ice, and then the fish are graded according to size. Depending on the plant, fish to be frozen whole are washed either manually or mechanically and transferred to freezing tunnels which quick freeze the fish at -45°C (-49°F). Further processing of the halibut into portions then takes place after shipment to a retail packaging firm. Processors that "fletch" the halibut grade them into lots of under 27 kg (60 lbs) and over 27 kg (60 lbs); the

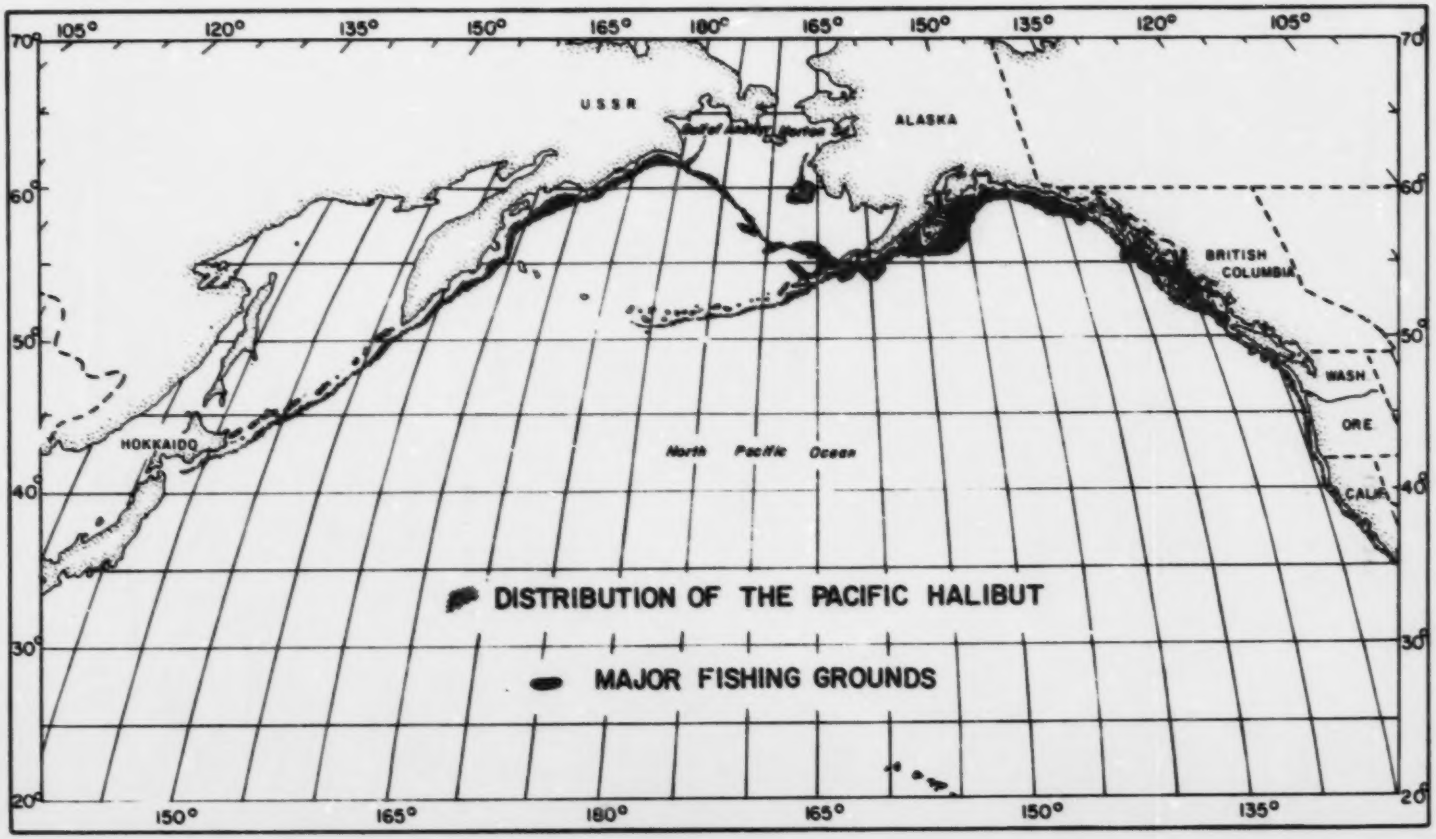

DISTRIBUTION OF THE PACIFIC HALIBUT
MAJOR FISHING GROUNDS
USSR
ALASKA
BRITISH COLUMBIA
WASH
ORE
CALIF
HOKKAIDO
North Pacific Ocean
105°
120°
135°
150°
165°
180°
70°
60°
50°
40°
30°
20°

Figure 12. Distribution of the Pacific halibut (8)

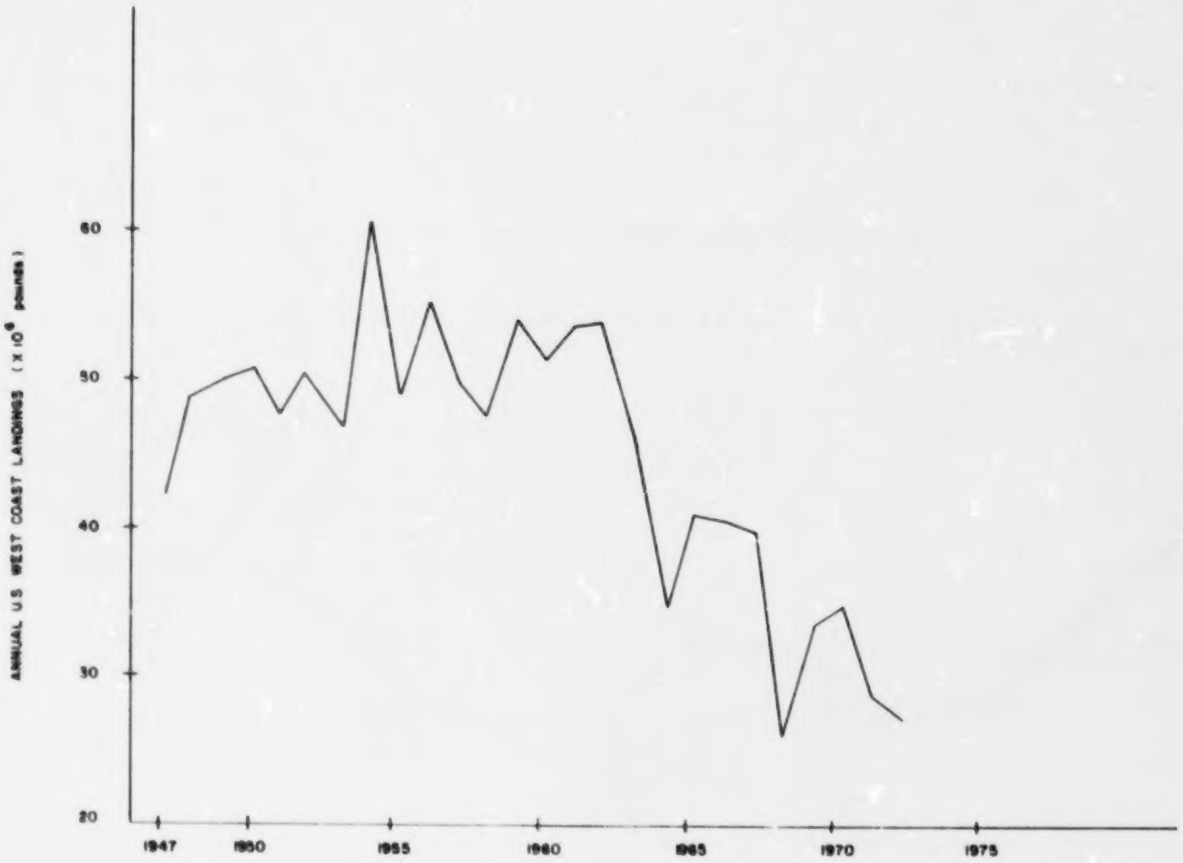


Figure 13. U.S. landings of halibut, 1947-1972 (6)

fish under 27 kg are frozen whole as previously mentioned. Those fish greater than 27 kg are butchered to remove four fletches. These sections are then trimmed, washed, and quick frozen. Larger trimmings are marketed to be smoked, breaded, etc., and the large fletches are usually distributed to institutional outlets from which steaks are then cut.

## Sea Herring

Atlantic herring (Clupea harengus harengus) are one of the most abundant food fishes in the North Atlantic, especially in the Gulf of Maine. The Pacific herring (Clupea harengus pollasi) fishery has never been large and has been steadily declining since 1952. The same is true of the Pacific sardine (Sardinops caeruleus), which has been on the decline since 1948; commercial landings ceased after 1949 in British Columbia, Washington and Oregon (3). A law was passed by the California legislature in 1967 establishing a moratorium on the taking of sardines in California waters. No Pacific sardines have been canned since 1968 (1).

The canning of small, immature fish as sardines is the most important use of Atlantic herring. The use of herring for reduction to fish meal has declined as the resource declined and as the value for direct human food increased. The filleting of both the Atlantic and Pacific herring is a small but expanding industry. Landings of sea herring in 1972 totaled 46,300 kkg (102 million lbs), up 17 percent from 1971 (1). The North Atlantic harvest comprised 85 percent of the 1972 total; Maine supplied well over half the sardines consumed in the United States.

## Sardines

The first United States commercial sardine canning operation was established at Eastport, Maine in 1871 and the industry has remained centered in that state. During the 1950's, the number of canneries averaged about 45; however, because of decreasing fish supplies, foreign competition, consolidation, and other factors, the number of active processing operations has decreased to 17 (10). Most of the plants are relatively old and are built on piling over the water. Figure 14 shows the U.S. production of canned sardines for the past 12 years.

Sardines are harvested by three methods: purse seines, weirs, and stop seines. Stop seines and weirs are used to trap the fish while they are in a cove at high tide. When the tide starts to recede the fish try to leave the bight and become entrapped in the net.

After the fish are caught the scales are removed prior to storing. The "pearl essence" from the scales is used in the

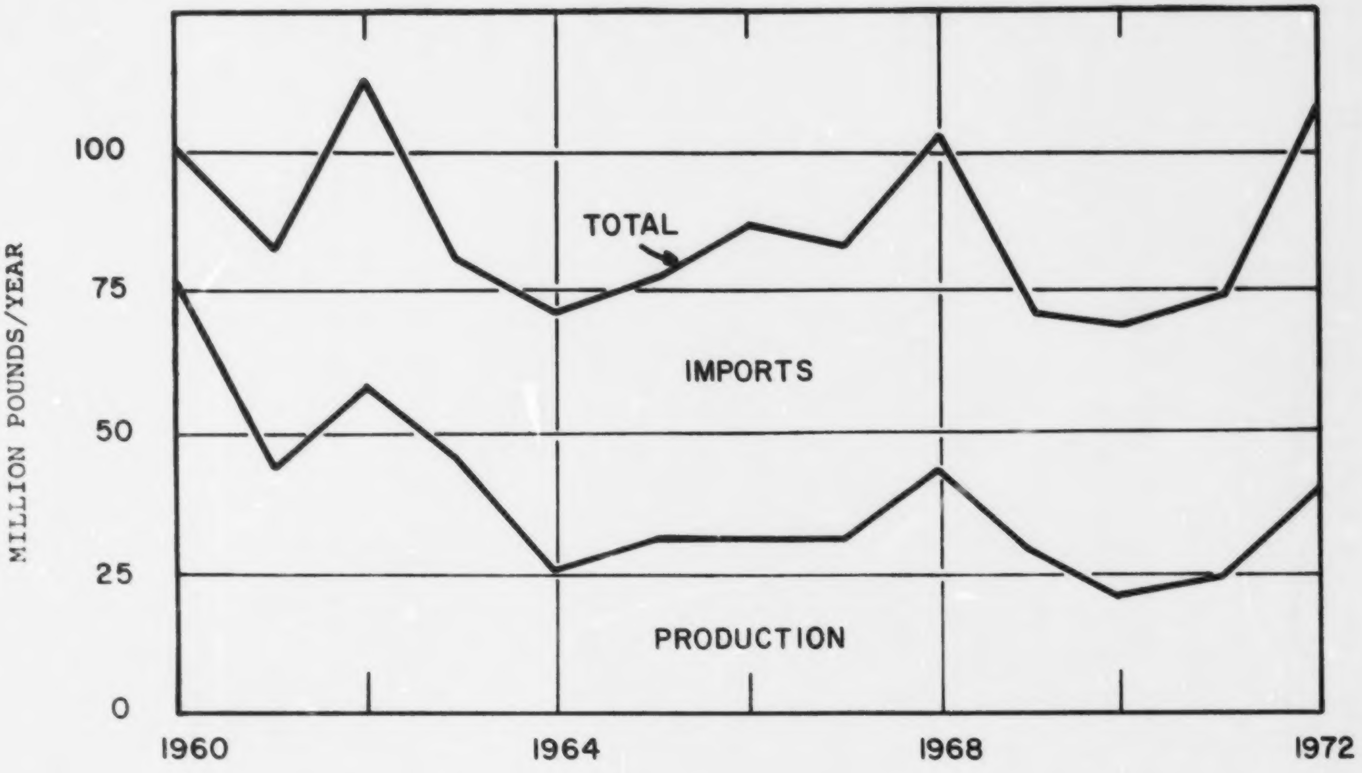


Figure 14. U.S. production and imports of canned sardines, 1960-1972 (1)

manufacture of cosmetics, lacquers, and imitation pearls. The fish themselves are salted down, layer by layer, to preserve them while in the hold. The fish are usually pumped out of the boat and transferred to refrigerated brine tanks for storage. They are then flumed or mechanically conveyed to the cutting tables, where the heads and tails are removed. Depending on size, four to twenty fish are hand-packed into the characteristic flat sardine can. The fish are then precooked in a "steam box" for 30 minutes in the open cans. The cans are then removed, drained, and oils or sauces are added, after which they are vacuum sealed. The sealed cans are retorted to sterilize the product prior to storage or shipment.

### Herring Filleting

Sea herring fillets are produced on both the East and West Coasts, with the processing centers located in Southeastern Alaska and in New England. The filleting operation is a relatively recent development, having been used in New England for only three years and having started in Alaska just last year. The market for herring fillets is expanding; the future of this new utilization method looks promising.

The fish are harvested and delivered to the processor in the same manner as described for the sardine canning operation. They are passed through a machine which first removes the head, tail, and viscera and then splits the fish into boneless sections or fillets. The fillets are sorted, boxed, and frozen for export. During the spawning season, the roe and milt are sometimes recovered and exported to Japan and England, respectively.

## SHELLFISH

The term "shellfish" in this report applies to those species of marine animals belonging to the following phyla: 1) mollusca, such as clams, oysters, abalone, scallops, and conchs; 2) arthropoda, such as lobsters; and 3) echinodermata, such as sea urchins. Shellfish processing is practiced along much of the U.S. coast, with both isolated and concentrated centers of production. In 1972, 86,000 kkg (190 million lbs) of edible shellfish were landed in the U.S., with a value of 380 million dollars (1). Table 13 summarizes the 1972 landings and values for the most important shellfish species. Statistics on landings for clams, oysters and scallops are shown in weights of meats excluding the shell. Landings for lobsters are shown in round (live) weight.

### Clams

The harvesting of clams accounts for about two percent of the volume of the landings in the U.S. seafood industry and 4.8 percent of the total value. The most important types are the surf, hard, and soft clams.

Table 13. U.S. landings of shellfish by species (1)

| Species | 1971 | | 1972 | | 1967-1971 (average) |
|---|---|---|---|---|---|
| | Weight (lbs) x 1000 | Value ($) x 1000 | Weight (lbs) x 1000 | Value ($) x 1000 | Weight (lbs) x 1000 |
| Clams: | | | | | |
| Hard | 17,216 | 17,025 | 16,336 | 18,501 | 16.206 |
| Soft | 11,829 | 6467 | 8769 | 5252 | 11,680 |
| Surf | 52,552 | 6905 | 63,441 | 7931 | 51,010 |
| Other | 1062 | 143 | 554 | 175 | 1374 |
| Oysters | 54,585 | 30,426 | 52,546 | 33,819 | 56,446 |
| Scallops: | | | | | |
| Bay | 1455 | 2428 | 479 | 786 | 1574 |
| Calico | 1566 | 783 | 1342 | 843 | 1019 |
| Sea | 6264 | 8829 | 6995 | 12,625 | 9386 |

About 87 percent of the clam harvest occurs in the mid-Atlantic region, with about 11 percent in New England and 2 percent in other areas. Of the clams harvested in the mid-Atlantic region, 61 percent are surf, 20 percent hard, and 17 percent soft, with 2 percent being miscellaneous species (1).

The surf clam (Spisula solidissina), also known as bar, hand, sea, beach, or skimmer clam, is found from the southern part of the Gulf of St. Lawrence to the northern shore of the Gulf of Mexico. Commercially harvested clams are found at depths of from 8 to 58 m (25 to 190 ft). The clams bury themselves to a depth of about 15 to 20 cm (6 to 8 in.) in a a substrata of gravel, sand, or muddy sand. Their size varies with geographic location. In the most productive area, from Long Island to Virginia, the clams range from 15 to 22 cm (6 to 8-3/4 in.). The marketed clams average 5 to 6 years in age; natural life spans are about 17 years.

Surf clams are harvested all year, weather permitting, for 8 to 12 hours per day, about 20 miles from shore, using a 1 to 2 m (3 to 6 ft) wide steel dredge. A hose pumping about 5700 to 11,000 l of water per minute (1500 to 3000 gpm) breaks up the ocean bottom in front of the dredge, enabling the clams to be loosened and netted. A full dredge yields from 760 to 910 l (25 to 30 bu) (11).

The processing of surf clams consists of three basic operations: shucking, debellying, and packing. The clams are either mechanically or hand shucked. Hand shucking operations generally use a hot water cooker before removing the clam from the shell. Mechanical operations use a steam cooker or a shucking furnace. The meat is then removed from the shell by the use of a brine flotation tank. The shells are stockpiled and utilized in landfills or road construction or piled to dry for subsequent use as media for shellfish larvae attachment.

The clams are often debellied manually, although there is a trend to automate this operation. The viscera and gonads removed from the surf clam are either dumped directly into the adjacent receiving waters, or saved for bait or hog food. There are several final products: fresh pack as whole clams, canned, and frozen clams.

The several washing operations result in a high volume of wastewater, especially in the mechanized plants.

## Hard Clams

"Hard clam" refers to a quahog or quauhog (Meicenania mencenania Venus meicenania, Cyprina islandica, Arlica islandica), butter clam (Saxidonus nuttali), and little neck clam (Papes staminea). The hard clam, also known as cherry stone, chatter, little neck, or round clam, is found from the Gulf of St. Lawrence to the

Gulf of Mexico with a few Pacific Coast locations; however, the main centers of industrial activity are Massachusetts, Rhode Island, New York, North Carolina, Florida and Washington.

The adult clam is 5 to 10 cm (2-4 in.) long. It is found on sandy, muddy substrata from the high tide line to depths of about 18 m (60 ft) and 24 to 46 m (80 to 150 ft) deep, three to twelve miles off shore. The clam meat has a similar chemical composition to oyster, but contains more protein per unit weight. Manual means such as rakes, and oyster tongs are used inshore, whereas, power operated Nantucket-type dredges are used offshore. The dredge acts as a multi-toothed plow, digging through the bottom and scooping the shellfish into an attached bag.

Ocean quahogs are harvested all year and the clam beds, unlike inshore areas, remain unmanaged. The clams arrive at the shucking houses by truck 15 to 30 hours after being harvested. They are then washed and shucked into metal colanders, washed, weighed, and packaged. The operation is very similar to a manual oyster shucking operation. The hard clams have a longer frozen shelf life than the other clams; however, a few are sold fresh for use in chowder (12).

## Soft Clams

The soft clam (Mya anenonia) is located on the East Coast from Labrador to North Carolina, with a few locations on the West Coast. The economically important centers range from Maine to Massachusetts and the Chesapeake Bay region. It is a small industry which operates in conjunction with the oyster and blue crab business. Clams are processed all year except during bad weather, in parts of the summer when normal dieoff takes place, and when water quality fails to meet state regulations.

In New England, where the soft clams are mainly intertidal, hand forks or hand hoes are the dominant harvesting techniques. The hydraulic dredge is used in the Chesapeake Bay area. The dredge utilizes water pressure to disturb the bottom sediments and a conveyer belt brings the clams from the 2.5 to 6 meter (8 to 20 ft) depth to the surface, where the mature clams are sorted out. At the present time, about 21,000 cu m (700,000 bushels) are harvested by 150 licensed dredgers per year in the Chesapeake Bay area (13).

The number of clam beds is being reduced by a combination of factors such as pollution from municipal and industrial wastes, high temperatures, siltation, low salinity and dredging which has stunted growth and led to high bacterial counts. The market demand is increasing due to the increasing use of the surf clam. Recent trends are toward further processing using breading and for chowders.

The processing of soft clams is very similar to the processing of hand shucked oysters. The entire clam is removed from the shell, washed, fresh packed, and shipped for further processing since they are rarely eaten raw. Those which are not fresh packed are canned, sold in the shell, or used for bait by fishing boats. Most plants are small, employing 8 to 30 shuckers (12).

## OYSTERS

The three species of oyster important in the United States are the American, Eastern, or Virginia oyster (*Cassostrea virginica*), the Japanese or Pacific oyster (*Cassostrea gigass*), and the Olympia or native oyster (*Ostrea lurida*). The eastern oyster is found on the east coast of North America and on the Gulf Coast. In the north it takes four to five years to reach a marketable size of 10 to 15 cm (4 to 6 in.) and less than one-and-one-half years in the Gulf. Pacific oyster seed originates in Japan and is planted along the West Coast. The shell is elongated and grows to 30 cm (12 in.) or longer. The Olympia oyster, native to the Northwest, rarely exceed six cm (2.75 in.) (14).

Oysters are marketed in the shell, fresh packed, steamed, smoked, frozen, breaded, and in chowders and stews. A large amount is utilized by restaurants. The shell is used commercially as poultry food, in fertilizer, concrete, cement, pharmaceuticals, road construction, and as media for oyster larvae attachment.

Harvesting varies according to the area. On the West Coast, the oyster seed used is sent from Japan annually and may be strung on wires which are suspended from wooden racks, which are then suspended in the water. After a year the wires are cut, allowing the oysters to continue to grow on the bottom.

In New England, oysters are harvested by large suction dredges, with most of the beds being privately owned and managed. In contrast, only antiquated techniques are allowed by State law in Maryland's Chesapeake Bay. Harvesting occurs between September 15 and the end of April using hand tongs and sail dredging. In Virginia, the season is from October to March on public grounds and all year on beds leased from the State. Oysters are harvested using a boat towing a four foot wide dredge. The dredge acts as a plow, digging through the bottom and scooping the oysters into attached bags. In the southern states the oyster flats are often exposed at low water and hand picking, grabs, and hooks are most often used. Overall, dredges harvest about 63 percent; tongs, about 36 percent; and forks, rakes, and hand picking, the remainder.

The harvest of oysters in the United States by all methods totals about 22,000 to 27,000 kkg (50 to 60 million lbs) live weight. About 80 percent of the total production is taken from the Chesapeake Bay and Gulf Coast regions, with the largest volume landed in the Chesapeake Bay, particularly in Maryland (15).

Figure 15 reviews the history of oyster meat production in the United States by region.

Aquaculture, using techniques developed by the Japanese, is being used increasingly to raise production. It has been found that by "artificially" optimizing conditions more oysters can be grown per unit area of bottom, the growth rate can be doubled, they can be grown in areas where the bottom is unsuitable, the quality of the meat is improved, and predator loss is reduced. Figure 16 shows a comparison of the growth of raft and bottom grown oysters at one location in New England. Today, Japan uses aquaculture nearly exclusively and harvests 21 kkg (23 tons) of meat per acre per year; the United States averages about 2 tons per acre per year.

There are several factors which will influence the oyster industry in the future. The application of scientific techniques must increase to raise production. Due to a shortage of workers and high labor costs, mechanical shucking devices must be designed. It may be possible to increase production by developing hybrids which are faster growing, disease resistant, better adapted to environmental conditions, uniform in size and shape, and more prolific. Oysters are very sensitive to environmental conditions. The number of acres from which oysters can be harvested has been decreasing yearly and low cost foreign imports have been cutting into the American market.

The process for hand shucked oysters is essentially the same, regardless of species, plant size, or location. On the West Coast, the oysters are unloaded from the boat at the plant by hand or conveyor belt and washed by nozzles suspended above the belt. On the East Coast, more of the oysters are trucked to the plants. The oysters are then shucked, washed, and fresh packed in jars or cans.

Oyster canning, in this country, is rapidly becoming uneconomical due to the import of Japanese and Korean products. Broken oysters are sometimes canned as stew. The oysters are first cooked with spices and preservatives in large vats for 30 minutes. The meat is then added to the cans along with whole milk and butter, sealed and retorted.

The steamed oyster process, which is used in the Middle Atlantic, is considerably more mechanized than the hand shucked oyster process. The oysters are first mechanically shucked to jar the shells far enough apart to allow steam to enter during the cooking. After steam cooking, the meat is separated using brine flotation tanks, washed and packed into cans. The juice from the steaming operation is added to the can before sealing. A small number of oysters are also smoked. The shucked oyster is smoked with apple wood or other hardwood species. The meat is then placed in a glass or tin with a small amount of vegetable oil and sealed.

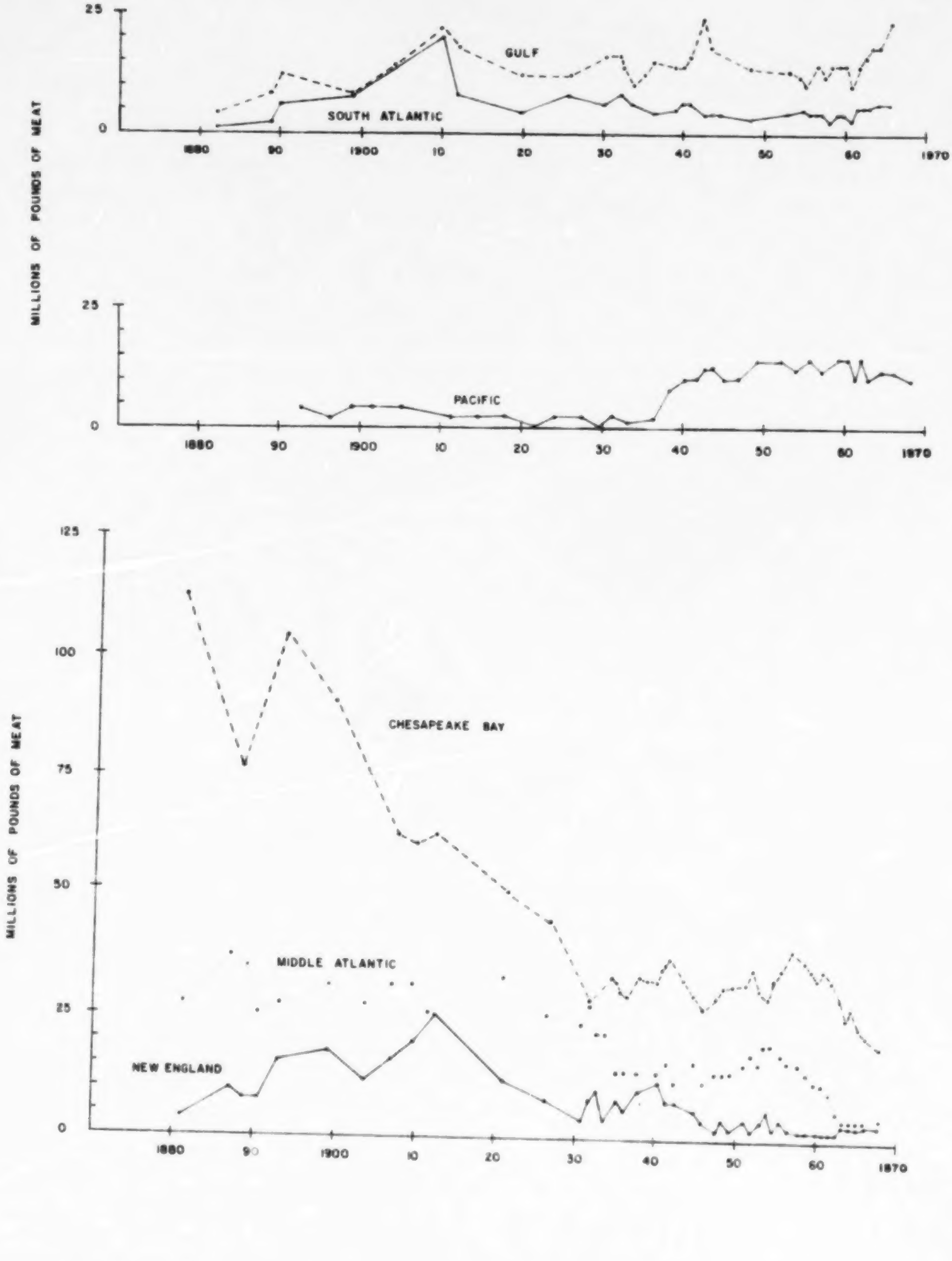


Figure 15. Oyster meat production by region (18)

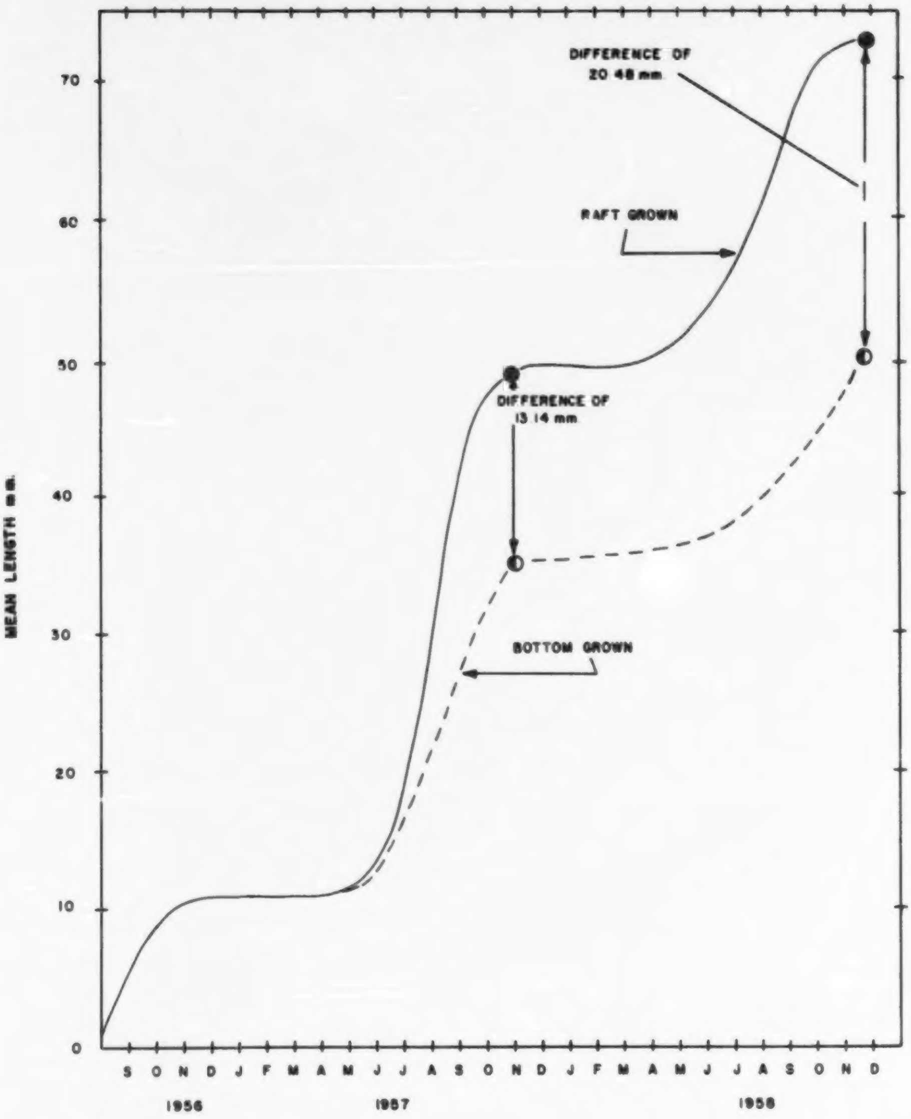


Figure 16. Comparison of raft-and bottom-grown oysters (18)

## Scallops

Four species of scallops are economically significant in the United States: bay scallops (*Aequipecten irradians*), calico scallops (*Pecten gibbus*), sea scallops (*Placopecten magelanicus*), and Alaskan scallops (*Platinopecten carinus*). In this report, sea and Alaskan scallops will be treated collectively as sea scallops. The total scallop harvest in the United States has been steadily declining, with the 1972 landings being 21 percent lower than the five year average. Table 14 shows the scallop landings by species for the last 10 years.

Of the three species of scallops harvested in the United States, sea scallops comprise the majority of the landings, constituting an average of 78 percent of the total catch for the 1968-1972 period. Bay scallop landings averaged 13 percent of the total for the five year period. Calico scallops, a relatively new resource, comprised the remaining 9 percent of the average catch from 1968-1972. The calico scallop fishery is centered in the Cape Canaveral area of Florida and in North Carolina. Estimates for the future indicate that all species are being harvested below the level of maximum sustainable yield, but calico scallops are virtually untapped as a resource.

The 1972 harvest of calico scallops was less than one percent of the estimate of the maximum sustainable yield. The calico scallop is very temperature sensitive, which causes great fluctuations in the harvest. The 1973 market was poor due to low temperatures, with only about 1200 kg (2600 lbs) of meat obtained; however, January, 1974 was reported to be a very good month (16).

Scallop harvesting is usually accomplished by scraping the bottom with iron dredges of varying design. Sea scallops and calico scallops are usually found on sandy or rocky bottoms at depths up to 270 m (150 fathoms). Most dredging is conducted 12 or more miles from the coast. Sea scallops are commercially harvested along the Atlantic Cost from Maine to Virginia, with the larger Alaskan species currently being harvested only in the Gulf of Alaska. Calico scallops inhabit warmer waters, and are commercially harvested from North Carolina to the east coast of Florida. Bay scallops reside in eel grass on sandy or muddy flats of bays and estuaries along the Atlantic Coast from Massachusetts to Florida. Harvesting is accomplished either with dredges or with dip nets and rakes, and the scale of operation is much smaller than that of sea scallops.

Processing is similar for the sea and bay scallops. To avoid degredation scallops are hand shucked immediately after landing on the vessel. The shell closing muscle is removed and placed in muslin bags which are held on ice for shipment to the processing plant, and the remainder of the organism is discarded overboard. The processing of sea and bay scallops involves only a washing and freezing operation; hence, the effluent has a small waste

Table 14. Scallop landings by species, 1963-1972 (1)

| Year | U.S. Landings x 1000 lbs |  |  |  | Imports x 1000 lbs |
|---|---|---|---|---|---|
|  | Bay | Calico | Sea | Total |  |
| 1963 | 1517 | -- | 19,939 | 21,456 | 13,397 |
| 1964 | 1887 | -- | 16,914 | 18,801 | 16,175 |
| 1965 | 1859 | 872 | 20,070 | 22,801 | 16,495 |
| 1966 | 1780 | 1857 | 15,975 | 19,612 | 16,712 |
| 1967 | 1097 | 1410 | 10,243 | 12,750 | 13,461 |
| 1968 | 1491 | 89 | 13,818 | 15,398 | 14,581 |
| 1969 | 2114 | 199 | 9312 | 11,625 | 14,322 |
| 1970 | 1700 | 1833 | 7304 | 10,837 | 16,830 |
| 1971 | 1455 | 1566 | 6264 | 9285 | 17,387 |
| 1972 | 479 | 1342 | 6995 | 8816 | 20,820 |

load. The calico scallop process involves a heating operation which opens the shell to facilitate the shucking and evisceration.

## Abalone

Eight species of abalone are found off the West Coast of the United States, four of which comprise the bulk of the commercial catch. These are the red, pink, white, and green varieties: Haliotus rufescens, H. corrugata, H. sorenseni, and H. fulgens, respectively. The abalone range extends from Sitka, Alaska through Baja, California; however, the commercially important species are concentrated in the California area from Monterey to San Diego.

Abalone are relatively large gastropods which are found from the intertidal zone out to deep water. The shells of the harvested animals range from about 10 to 25 cm (4 to 10 in.). Abalone feed almost exclusively on macroalgae and thus, are concentrated in and around areas where large amounts of these algae flourish. Although utilized by the Indians for thousands of years, abalone were not commercially collected until the early 1850's. Rapid depletion of the resource soon prompted the passing of a law in 1900 making it unlawful to fish commercially for abalone except in deep water. Figure 17 summarizes the history of abalone landings in California.

Restricted to deeper water, various diving methods have evolved from early Japanese "sake barrel" diving, to the hard hat method, and to the present use of light-weight gear. However, California commercial fish laws still require the diver to be supplied by a surface air source, thereby excluding scuba gear from all except the sport fishery. Divers operating in 8 to 24 m (25 to 80 ft) of water measure their catch, then pry the abalone off the medium and collect it in a mesh basket which is hauled aboard the boat by the surface tender. The tender boat, which may serve one or more divers, then transports the catch to a receiving area from which it is trucked to the various processing plants.

At the processer the abalone are shucked; then the large foot muscle is cleared of viscera and washed. The outer sheath of the muscle is trimmed off, the head portion removed, and it is then sliced into several steaks. The steaks are pounded to tenderize them before packaging and freezing. The usual product form is either fresh or frozen steaks which may or may not be breaded at the plant.

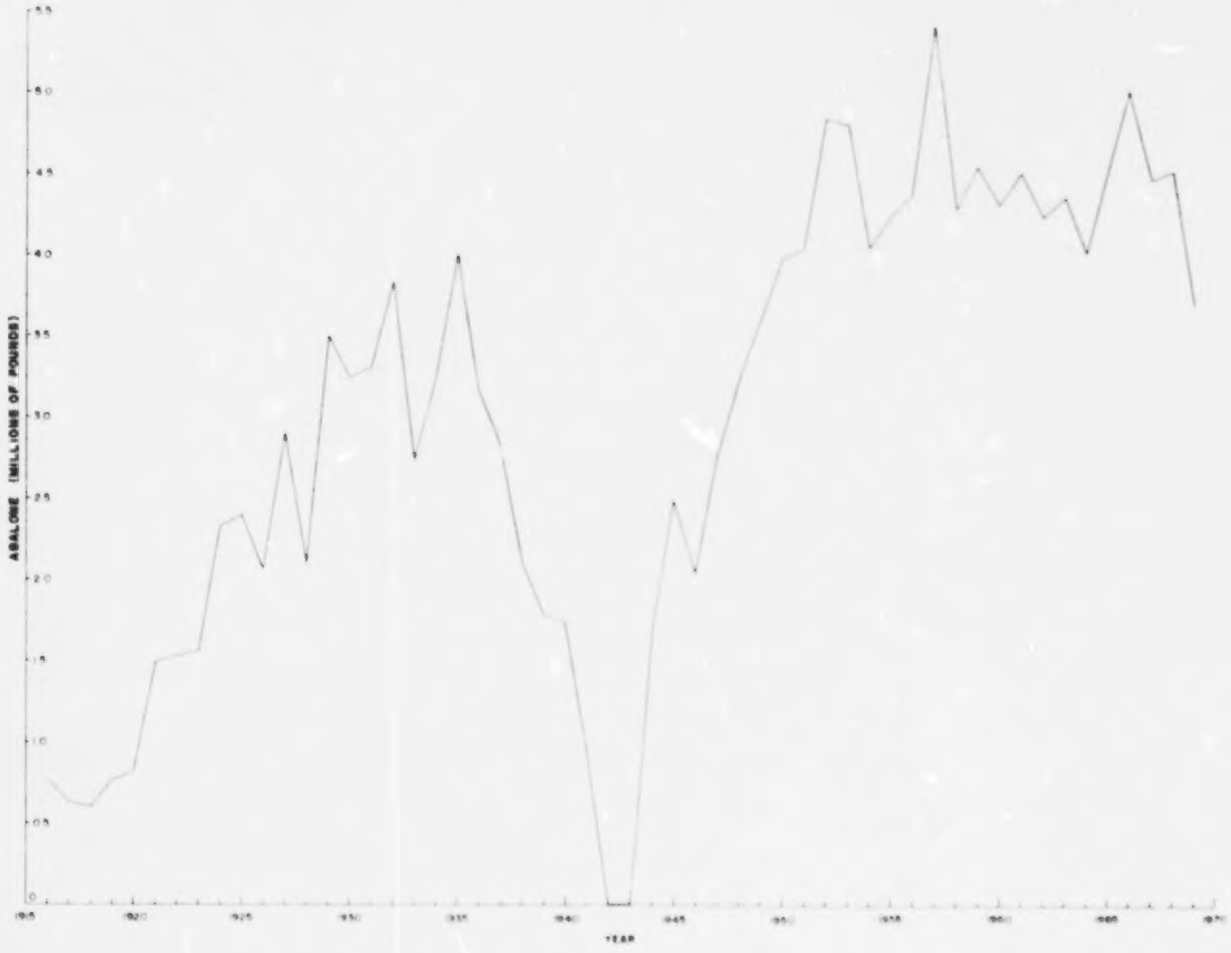


Figure 17. California abalone landings (3)

# SECTION IV

# INDUSTRY CATEGORIZATION

## INTRODUCTION

The objective of categorization is to organize the industry into segments whose uniqueness and internal homogeneity suggest the consideration of separate effluent limitations. The initial categorization of the fish meal, salmon, bottom fish, clam, oyster, sardine, scallop, herring, and abalone segment of the seafood processing industry study fell along commodity lines. The advantage of initial commodity categorization is that it automatically segments the industry into relatively homogeneous groups, in terms of: type and variability of raw product utilized, manufacturing processes employed, wastewater characteristics, typical plant locations, and (often) economic stature, geographic regionalization, and production levels. First, three broad groups of subcategories: industrial fish, finfish, and shellfish, were established because of basic differences in processes or species. Excluded were the four commodities covered under a previous study (Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Catfish, Crab, Shrimp, and Tuna Segment of the Canned and Preserved Seafood Processing Point Source Category, June 1974, EPA-440/1-74-020-a). Since this study covered a large number of commodities, the approach was to group the industry into the "more significant" and "less significant" wastewater sources to make the most effective use of the time and money available.

Through preliminary contacts with the industry and with experts close to the industry, a "relative importance matrix" was developed. This matrix used four basic parameters to determine an "importance score" for each of several seafood commodities. These parameters were: 1) organic waste loading (kg BOD/day), 2) flow (cu m/day), 3) number of plants, and 4) season variability. A score of "one" or "zero" was assigned to each element in the matrix and a total score obtained for each commodity by adding the individual scores. A high score indicated that a relatively large effort should be exerted to characterize the waste from that segment of the industry; and a low score, a relatively small effort. Tables 15 and 16 show the results of the matrix analyses for the finfish and shellfish commodities, respectively.

Consultants and other knowledgeable persons in the particular industry, government organizations, and universities were contacted to determine specifics about major processing areas, identities of plants, typical processing operations, seasons, raw products utilized, production rates, and treatment facilities. Typical plants with processing operations that are commonly used, and with average water use and production rates were identified.

Table 15. Relative importance matrix--industrial fish and finfish.

| Commodity and Process | Load (BOD/ day) | Flow (volume/ day) | Size (number of plants) | Seasonality | Score |
|---|---|---|---|---|---|
| Menhaden reduction | 1 | 1 | 1 | 0 | 3 |
| Anchovy reduction | 1 | 1 | 0 | 0 | 2 |
| Salmon canning | 1 | 1 | 1 | 1 | 4 |
| Sardine canning | 1 | 1 | 0 | 1 | 3 |
| Bottom/ misc. finfish (conventional) | 0 | 0 | 1 | 0 | 1 |
| Bottom/ misc. finfish (mechanized) | 1 | 1 | 1 | 0 | 3 |
| Fresh/ frozen salmon | 0 | 0 | 1 | 1 | 2 |
| Halibut freezing | 0 | 0 | 1 | 1 | 2 |
| Herring filleting | 1 | 1 | 0 | 1 | 3 |
| Fish flesh | 1 | 0 | 0 | 0 | 1 |

Table 16. Relative importance matrix--shellfish.

| Commodity and Process | Load (BOD/ day) | Flow (volume/ day) | Size (number of plants) | Seasonality | Score |
|---|---|---|---|---|---|
| Clam meat (mechanized) | 1 | 1 | 1 | 0 | 3 |
| Clam meat (hand shucked) | 0 | 1 | 1 | 0 | 2 |
| Fresh/ frozen oysters (hand shucked) | 0 | 0 | 1 | 0 | 1 |
| Steamed/ canned oysters | 1 | 1 | 1 | 0 | 3 |
| Abalone | 0 | 0 | 0 | 0 | 0 |
| Scallops | 0 | 0 | 0 | 1 | 1 |

The field investigations were organized on a regional basis by locating areas where suitable plants and industries tended to be concentrated. The number of locations, plants, and samples required to obtain the desired information were determined with the help of the importance matrix. It was estimated that there were about eight commodities with potentially high pollutional significance, about twelve commodities with potentially medium significance, and several other commodities of minimal signficance.

A maximum of 1000 samples was allocated for this study. The commodities of greatest pollutional significance were characterized more accurately (by investigating more plants and taking more samples) than those of lesser significance. About 60 to 70 space-time total effluent and unit operation samples were budgeted for each of the most important commodities. The unit operations samples would be used to estimate material balances and to indicate areas where process changes could reduce the waste load. Medium-importance commodities were budgeted about 30 to 40 space-time samples each of total effluent unit operations. The commodities of minimal importance were budgeted about 100 samples total. As the study progressed and more information was obtained, the emphases on certain commodities changed. Those commodities producing less waste than anticipated were sampled less frequently and those producing more, were sampled more frequently.

In addition to collecting water samples, the field crews kept daily logs reporting on factors regarding the plant and its environment.

All data were reviewed and final subcategorization made based on the following major factors: 1) form and quality of finished product (commodity); 2) manufacturing processes and unit operations; 3) wastewater characteristics (particularly flow, total solids, 5-day BOD, and grease and oil); and 4) geographic location (particularly Alaska or non-Alaska). Several other factors, such as variability in raw product supply and production, condition of raw product on delivery to the processing plant, variety of species being processed, harvesting method, degree of preprocessing, age of plant, water availability, and amenability of waste to treatment were also considered. It was determined that these other factors were highly correlated with one or more of the major factors.

Variability of raw product supply and production is strongly correlated with the type of product being processed and occasionally with geographic location and production capacity.

For example, all operations producing canned salmon have highly variable raw product supplies, with the variations being most extreme in some parts of Alaska. This necessitates large production capacities to allow utilization of the raw product during the short time that it is available.

The condition of the raw product on delivery to the plant is generally related to the finished product and occasionally to geographic location. Many shellfish typically arrive at the plants fresh (e.g., clams, oysters, lobsters). Seasonal variations within some commodity groups may change the wasteload; however, the duration of this study and the frequent lack of sufficient historical data bases made estimation of the quantitative effect on the wastewater impossible. Qualitatively, raw product condition variability within a commodity group is considered to be a second order effect, which does not warrant the establishment of separate effluent limitations.

The variety of species utilized in each commodity group is usually limited to those which are quite similar. In general, the processes which have the largest capacities and produce the most waste have the fewest species. Those which handle a large variety of species, such as conventional bottom fish processes, are typically smaller and utilize manual unit operations, which produce lower waste loads. It was not considered necessary to establish separate effluent limitations based on species when they were processed in a similar manner and the waste load from any one type was minimal.

Harvesting methods are generally similar within a commodity group. Different methods only affect the condition of the raw product and/or the degree of preprocessing. Therefore, this factor does not have to be considered as a separate variable for the establishment of subcategories.

The degree of preprocessing can be an important influence on wastewater quality. However, this is included under the consideration of the unit operations, which is one of the major factors. The greater the degree of preprocessing, the fewer unit operations are utilized in the processing plant.

The ages of the plants were considered to be minor factors in the establishment of subcategories, since similar unit operations are generally employed in both old and new plants for a particular type of process. Furthermore, the plant age seldom correlated with the age of the processing equipment; to remain competitive (in most subcategories) the processors must employ efficient, up-to-date, well-maintained equipment. This factor tends to standardize each subcategory with respect to equipment type and (usually) age.

Raw water availability was not considered to be a factor for the establishment of effluent limitations since the in-plant and end-of-pipe control techniques recommended for the seafood industry involve reductions in water use.

The quality of the raw water does affect the quality of the effluent for some processes in certain regions and was considered in the establishment of effluent limitations. For example, large percentages of some waste loads in solubles plant effluents from fish meal plants are attributable to the poor quality of the intake water.

Amenability of the waste to treatment is an important factor but is included as part of the wastewater characteristics considerations. In general, the wastewater from seafood processing operations is amenable to treatment except for those cases where strong brines or pickling or preserving acids are being discharged. Even for these cases, dilution, although costly, will allow the wastes to be treated in conventional systems.

Additional considerations in subcategorization were "production capacity and normal operating level." By nature, the seafood industry is an intermittent process (controlled by product availability) and production capacity is governed by such constraints as the type of processing equipment utilized (especially manual versus mechanical) and the number of employees available. The evidence developed during the monitoring phase of this study indicates that waste load ratios based on production within a subcategory is independent of plant size or operating level as illustrated graphically in Figures 22, 23, 24, 30, 31, 32, 35, 36, 37, 46, 47, 48, and 59 through 64. However, the economic impact analysis indicates that the very small plants within the non-Alaskan conventional bottom fish processing subcategory, hand-shucked clam processing subcategory, Pacific Coast hand-shucked oyster processing subcategory, and the East and Gulf Coast hand-shucked oyster processing subcategory would absorb a disproportionate economic impact than the larger processors within these subcategories. Therefore, as specified in the Federal Register notice, application of the regulations depends on the size of the processing facility.

## FISH MEAL PRODUCTION

The processing of Atlantic menhaden and Pacific anchovy into meal, oil and solubles was considered to be one of the most important segments of the seafood industry, in terms of its significance as a wastewater source. A concerted effort, therefore, was made to exhaustively characterize the effluents and to obtain as much information as possible on methods of wastewater control for the industry. A total of eight plants in New England, the Middle Atlantic, the Gulf of Mexico and California were investigated and 191 unit operation and end-of-pipe composite samples of the wastewater collected.

### Process Description

A generalized process flow diagram for menhaden and anchovy wet rendering is presented in Figure 18.

Menhaden are delivered to the plant in the holds of large carrier vessels. Because of the volume of fish to be processed, the industry must employ fast, efficient means of unloading. A

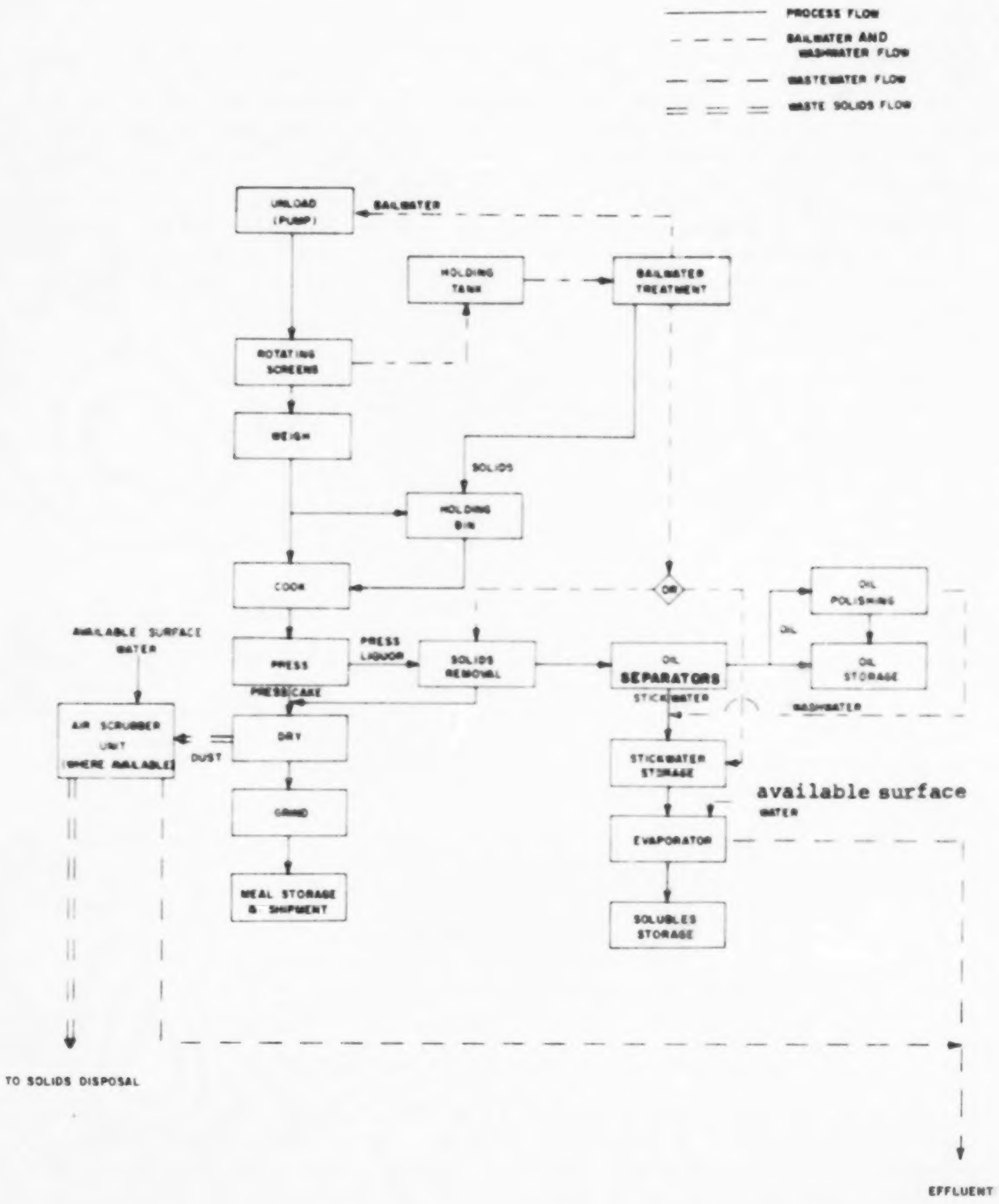

PROCESS FLOW
BAILWATER AND WASHWATER FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
UNLOAD (PUMP)
BAILWATER
HOLDING TANK
BAILWATER TREATMENT
ROTATING SCREENS
WEIGH
SOLIDS
HOLDING BIN
COOK
OR
OIL POLISHING
OIL
AVAILABLE SURFACE WATER
PRESS
PRESS LIQUOR
SOLIDS REMOVAL
OIL SEPARATORS
OIL STORAGE
PRESSCAKE
STICKWATER
WASHWATER
AIR SCRUBBER UNIT (WHERE AVAILABLE)
DUST
DRY
STICKWATER STORAGE
available surface WATER
GRIND
EVAPORATOR
MEAL STORAGE & SHIPMENT
SOLUBLES STORAGE
TO SOLIDS DISPOSAL
EFFLUENT

Figure 18. Typical large fish meal production process.

mechanized bailing system is generally used for this purpose. The operation consists of filling the holds with water (usually local estuarine water) and pumping the fish-water slurry with a reciprocating piston pump. Plants usually employ from one to three such pumps when loading 140 to 180 kkg (150 to 200 tons) of fish per hour (2). The pumps discharge over rotating or static screens, which separate the fish from the bailwater. These screens are generally followed by other (smaller mesh) rotating screens which remove much of the remaining scales and small pieces from the bailwater. The bailwater is then collected in large holding tanks located below the screens. These tanks range in capacity from 75 to 190 cu m (20,000 to 50,000 gal.).

As the bailwater is collected, it may be treated to remove suspended solids, or it simply may be recirculated. Treatment of bailwater may be effected with centrifugal decanters or dissolved air flotation units. Whether the bailwater is treated or not, it is usually retained and recirculated throughout the unloading process. The fish, once separated from the bailwater, are weighed and collected in holding bins, referred to as "raw boxes" in the industry.

Depending on plant location, anchovy are generally vacuum drawn from the boat holds directly into the processing plant. Some plants located inland transport the anchovy by tank truck. These fish are flushed out of the truck with high pressure hoses. The bailwater is normally recirculated, while the fish are dry-conveyed to the weighing room. From the weighing room they are conveyed to large holding bins from which they are augered into the reduction facilities.

The first step in the rendering process is the steam cook. The cookers are basically screw conveyers with steam injection ports located along their lengths. They are generally 9.1 m (30 ft) in length and 60 to 76 cm (24 to 30 in.) in diameter. The temperature at the inlet of the cooker is about 110°C (230°F) and at the outlet, about 116°C (240°F). The retention time of the fish in the cookers is about 10 to 15 minutes. Cooking is the most critical stage in the process. The fish are cooked to facilitate release of oil and water. Undercooking or overcooking results in excessive oil in the meal and poor oil recovery (17).

From the cookers the fish proceed to a battery of screw presses where the liquid and solid portions of the cooked fish are separated. The screw presses contain rotating augers whose flights progressively decrease in pitch along the major axis of the press. This causes increasing pressure to be exerted on the fish as they progress through the presses. Liquid passes out of each press through a cylindrical screen with perforations of decreasing diameter from 1.2 to 0.8 mm (0.05 to 0.03 in.). The fish solids exiting the press contain about 55 percent moisture and some oil. The press solids are referred to in the industry as "press cake."

The press cake is next conveyed to dryers to remove most of the moisture. Two classes of dryers are commonly used: direct dryers and indirect, steam jacketed dryers. The former is the more typical; however, indirect dryers are used in some plants. In the direct dryer, heat is generated by a gas flame. The gas from this combustion plus secondary air is passed, along with the wet press cake, through large rotating drums. The temperature at the entrance of the dryer is typically about 540°C (1000°F) and at the outlet of the dryer is typically about 93°C (200°F). Drying time is generally about 15 minutes. Hot air and vapors are drawn through the dryer at about 450 to 700 cu m/min (265 to 410 cu ft/sec), depending on the dryer size. The flow of hot air, fish meal, and vapor is passed through a cyclone which separates the meal from the air flow. The hot air, vapors, and volatiles from the dryers then pass through a scrubber system to remove most of the entrained organic material. The scrubber off-gases may then be recirculated to the dryer inlet and burned. Steam jacketed dryers cannot reburn the vapors. This sometimes necessitates the use of two scrubbers to reduce odors.

The meal is ground and stored for shipment. The liquid separated in the pressing operation is referred to as press liquor. It contains solid and dissolved fish protein, oil, fats, and ash. The larger solids are separated from the mixture by the use of vibrating screens and/or centrifugal decanters. The separated solids join the press cake flow at the drying operation. Oil is extracted from the press liquor by the use of centrifugal oil separators. These devices operate in a continuous manner, spinning the press liquor at a high velocity to effect a three phase separation of solids, oil, and stickwater by nature of their different densities. The oil produced in this process is usually refined or polished by the reintroduction of water, known as washwater. The oilwater mixture is then reseparated. This polishing removes fish protein and solubles which cause putrefaction of the oil during storage. The oil is then piped to large storage tanks and held for shipment. The water separated from the press liquor mixture contains dissolved and suspended protein, fats, oil, and ash. This mixture is termed "stickwater." As the stickwater is generated, it is piped to large tanks and stockpiled, awaiting further processing. At some plants it is joined there by the spent unloading water (bailwater) and washwater from oil polishing and from plant washdown. Further processing of stickwater involves concentration by evaporation. The stickwater is evaporated from a consistency of five to eight percent solids to one of about 48 to 50 percent solids. Typical for the industry is the triple effect evaporator, where a vacuum of about 0.87 atm (26 in. Hg) is placed on the third body while the first body is supplied with steam at 2 atm (absolute) and 121°C (15 psig, 250°F). The vapor from this first body is used to heat the second, and the vapor generated in the second, in turn, heats the third. The first effect will typically operate at ambient pressure (0 psig) and 100°C (212°F) with the second at 0.5 atm, 81°C (-7.5 psig, 178°F); and the third at 57°C, 0.13 atm (135°F, -12.8 psig). Two effects are sometimes used instead of three, and product flow direction may be opposite to that of the vapor. In addition, some plants operate with vapor from the first two effects feeding the third.

The stickwater exits from the evaporators at about 30 percent solids. From here it may enter one or two concentrators for further evaporation to 50 percent solids. The concentrators consist of steam-fed heat exchangers and evaporation bodies evacuated to 0.09 atm (-13.4 psig), termed "flash evaporators." The stickwater, which has been evaporated to 30 percent solids, enters the heat exchanger and, after heating to boiling temperature, it enters the flash evaporator. The stickwater is recirculated between the heat exchanger and flash evaporator until the proper concentration of solids is reached, at which point it is drawn off and pumped to the storage area.

A barometric condenser is used to place a vacuum on the evaporators. Condenser water is usually obtained from available surface water and is pumped 9 to 12 m (30 to 40 ft) above ground level and allowed to fall through the condenser and back to surface level. This condenser water entrains vapor produced in the last evaporator body and in the concentrators. The falling water is collected at the end of this pipe in an open tank called a "hot well." It is joined by evaporator condensate and is directed to the plant's outfall and discharged into nearby surface waters. The solubles plant discharge typically has a high flow (30,000 l/kkg; 7200 gal./ton) and low concentrations of BOD and suspended solids (less than 100 mg/l).

Stickwater and fish solubles tend to deteriorate rapidly during storage. This is usually prevented by adjusting the pH of the stickwater or solubles to 4.5 with sulfuric acid. It may be done before or after evaporation. If the stickwater is stored for a considerable period without being evaporated, the pH is usually adjusted before evaporation. The pH of the fish solubles resulting from evaporation is then readjusted to 4.5. However, if the plant can evaporate stickwater rapidly enough to avoid extended holding periods, no pH adjustment takes place before evaporation. After evaporation and pH adjustment, fish solubles are stored in large tanks to await shipment.

Small plants with no evaporator discharge the bailwater and stickwater, or barge them to sea. Some plants have sufficient evaporator capacity to evaporate the stickwater while still discharging the bailwater. Figure 19 shows the process flow diagram for a typical small wet rendering facility with no solubles plant. The discharge of stickwater and bailwater represents a very high waste load with concentrations of BOD and suspended solids typically in the tens of thousands (mg/l) and flows of 1900 l/kkg (460 gal./ton) or greater.

## Subcategorization Rationale

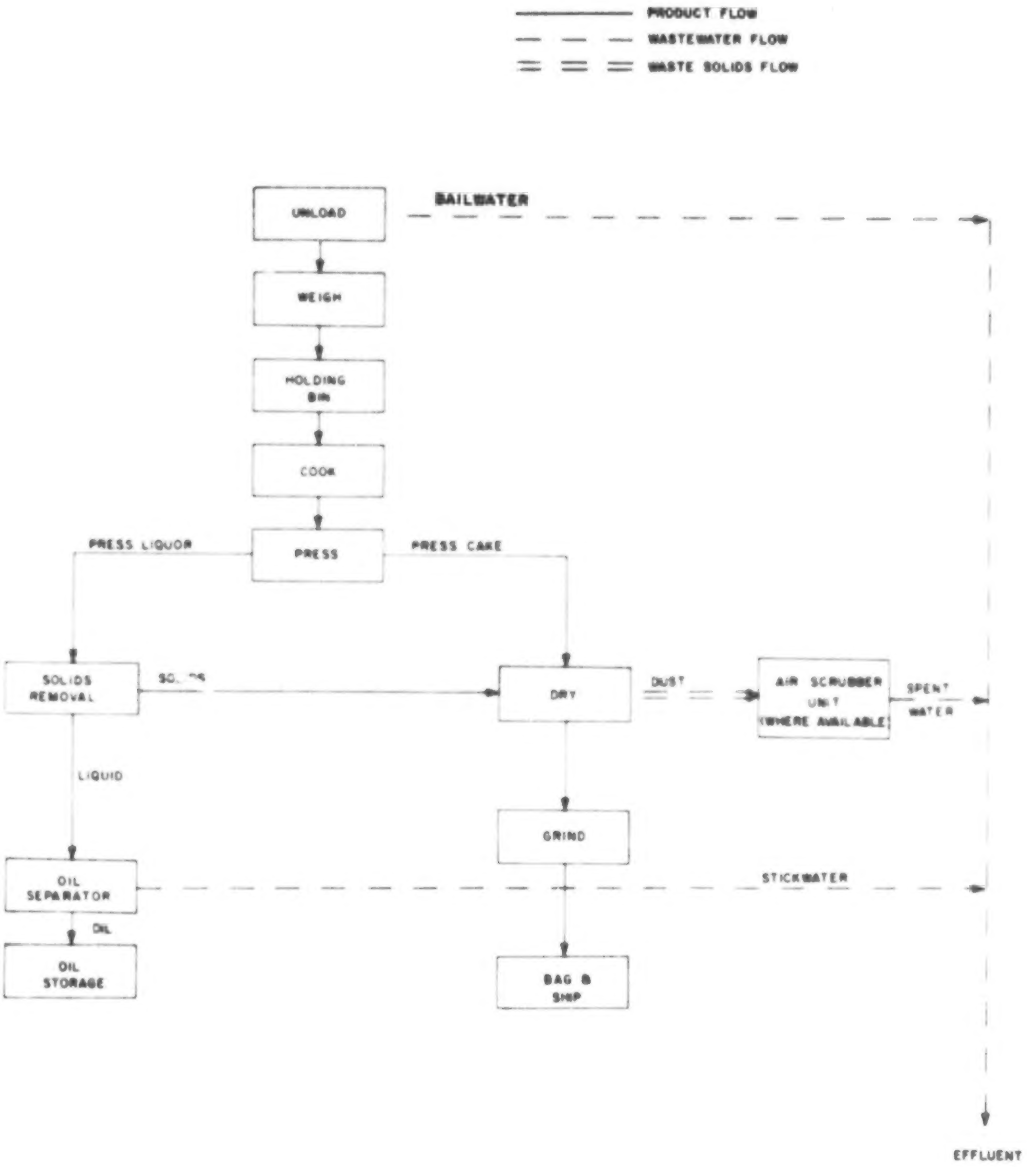

PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
UNLOAD
BAILWATER
WEIGH
HOLDING BIN
COOK
PRESS
PRESS LIQUOR
PRESS CAKE
SOLIDS REMOVAL
SOLIDS
DRY
DUST
AIR SCRUBBER UNIT (WHERE AVAILABLE)
SPENT WATER
LIQUID
GRIND
OIL SEPARATOR
STICKWATER
OIL
OIL STORAGE
BAG & SHIP
EFFLUENT

Figure 19. Typical small fish meal production process.

Regardless of the species being rendered, there are three general types of discharges from a wet reduction process: evaporator water, bailwater/washwater, and stickwater. In general, most large plants discharge only evaporator water. Some medium-size plants evaporate the stickwater but discharge the bailwater, and the smaller, older plants often discharge both stickwater and bailwater.

A total of eight fish meal plants were investigated. Historical information was also available from two of these plants prior to installation of bailwater utilization systems. A total of 56 end-of-pipe composite samples and a total of 145 unit operation samples were collected. Five of the plants were menhaden reduction plants located on the Atlantic and Gulf Coasts and three were anchovy reduction plants located in California.

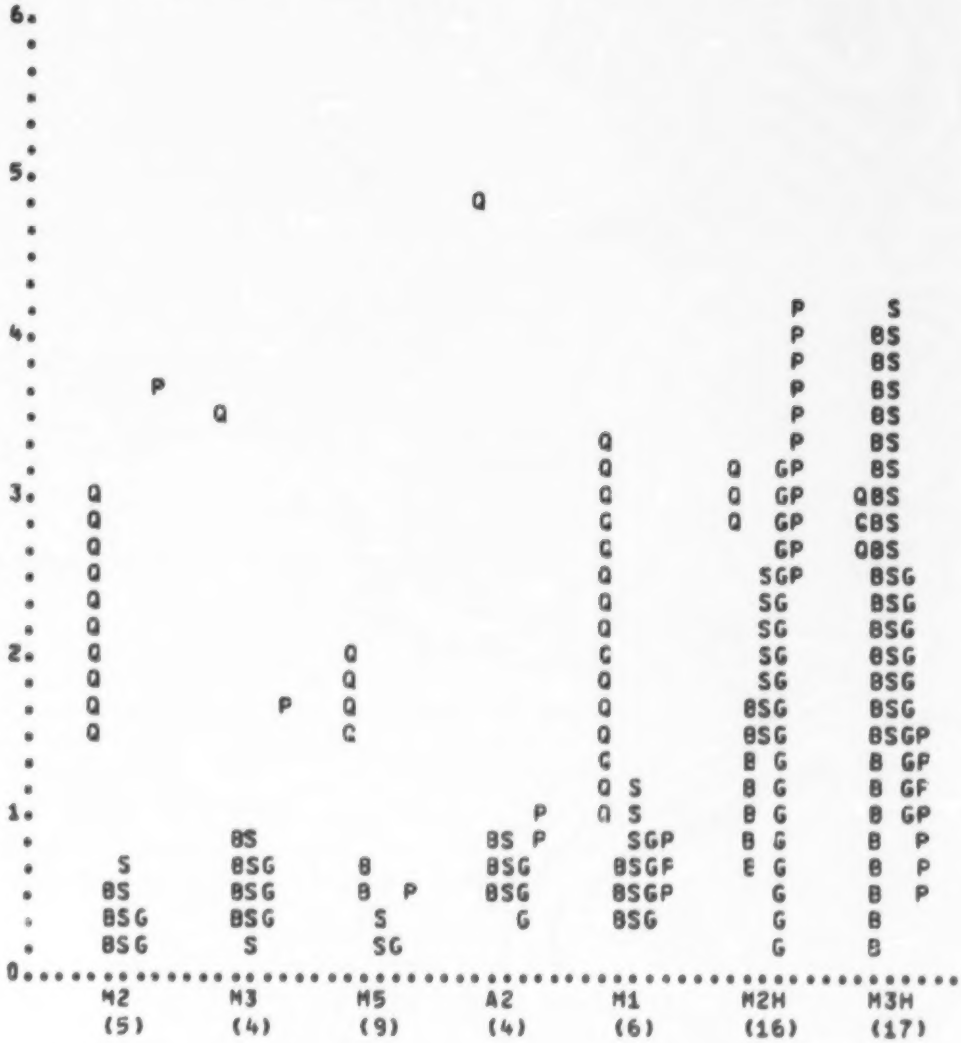
Figure 20 shows a normalized summary plot of the wastewater characteristics taken from all the fish meal reduction processes with solubles plants. Five parameters: flow, BOD, suspended solids, grease and oil, and production are shown for each plant sampled. The vertical scale is in inches with the scaling factor shown at the bottom of the figure. The average value of the parameter is at the center of the vertical spread with the height of the spread representing one standard deviation above and below the average. A plant code is shown at the bottom of each group, where "M" indicates menhaden and "A" indicates anchovy. The number in parentheses under the plant code is the number of flow-proportioned full-shift composite samples taken from each plant.

The four plants on the left (M2, M3, M5, and A2) discharged water only from the solubles plant while the three plants on the right (M1, M2H, and M3H) also discharged the bailwater instead of evaporating it. It can be seen that the waste load from the plants not discharging bailwater was generally lower. Plants M2 and M3 provided good examples of the reduction in waste loads that can be achieved by bailwater evaporation. The codes M2H and M3H represent historical data collected when both plants discharged or barged bailwater, while the codes M2 and M3 represent recent data when both plants were treating and evaporating the bailwater. Note that water use was not reduced when the plants were modified; the flow reduction realized by eliminating bailwater discharge was more than offset by the necessary increase in condenser dropleg flow. Table 17 shows the average waste loads both before and after bailwater treatment and evaporation and the percent reduction obtained.

Figure 21 shows a summary of the waste loads from two plants discharging both stickwater and bailwater. The waste loads were on the order of 20 to 40 times greater than those of the plants utilizing evaporators.

Table 18 summarizes the average waste loads from plants with three types of discharges: Solubles plant only, solubles plant plus bailwater, and stickwater plus bailwater discharge. Table

Figure 20. FISH MEAL PROCESS PLCT (WITH SOLUBLES PLANT).



| SYMBOL | PARAMETER | SCALING FACTOR |
|---|---|---|
| Q | FLOW | 1 INCH = 10000 L/KKG |
| B | 5 DAY BOD | 1 INCH = 5 KG/KKG |
| S | SUSPENDED SOLIDS | 1 INCH = 2 KG/KKG |
| G | GREASE & OIL | 1 INCH = 2 KG/KKG |
| P | PRODUCTION | 1 INCH = 20 TON/HR |

Table 17. Fish meal waste load reduction using bailwater evaporation.

| Parameter (kg/kkg) | Plant M2 | | | Plant M3 | | |
|---|---|---|---|---|---|---|
| | Before | After | Reduction | Before | After | Reduction |
| BOD | 5.9 | 1.7 | 71% | 10 | 3.6 | 64% |
| Suspended Solids | 4.1 | 0.9 | 78% | 5.6 | 1.2 | 79% |
| Grease and Oil | 3.0 | 0.5 | 83% | 3.5 | 1.0 | 71% |

Figure 21. FISH MEAL PROCESS PLOT (WITHOUT SOLUBLES PLANT)

```
6.
 .
 .
 .
 .
 .
5.
 .
 .                                       S
 .                                      BS P
 .                                      BS P
 .                                      BS P
4.                                      BS
 .                Q                     BS
 .                Q   P                 BS
 .                QB  P                 BS
 .                QB  P                 BS
 .                QB  P                 BSG
3.                QB  P                 BSG
 .                QB  P                 BSG
 .                QB                    BSG
 .                QB                    BSG
 .                QB                     SG
 .                QB                     SG
2.                QB                     SG
 .                QBS                    SG
 .                QBS                    SG
 .                QBS                    SG
 .                QBSG                   SG
 .                 BSG                   SG
1.                  SG                    G
 .                  SG                    G
 .                  SG                    G
 .                  SG
 .                   G                 Q
 .                   G
0...........................................................
                  A1                    A3
                  (3)                   (5)

  SYMBOL        PARAMETER                SCALING FACTOR
 --------------------------------------------------------
     Q       FLOW                  1 INCH = 5000  L/KKG
     B       5 DAY BOD             1 INCH =   20  KG/KKG
     S       SUSPENDED SOLIDS      1 INCH =   20  KG/KKG
     G       GREASE & OIL          1 INCH =   20  KG/KKG
     P       PRODUCTION            1 INCH =    2  TON/HR
 --------------------------------------------------------
```

Table 18. Summary of average waste loads from fish meal production.

| Parameter (kg/kkg) | Solubles Plant | Solubles Plant and Bailwater | Stickwater and Bailwater |
|---|---|---|---|
| Suspended solids | 1.0 | 3.8 | 41 |
| BOD | 2.9 | 6.1 | 59 |
| Grease and oil | 0.7 | 2.5 | 25 |

Table 19 Unit operation waste characteristics for fish meal processing without a solubles unit (Plant A3).

| Unit Operation | Flow l/kkg (% of total) | BOD5 kg/kkg (% of total) | TSS kg/kkg (% of total) | G&O kg/kkg (% of total) |
|---|---|---|---|---|
| Stick water (press liquor) | 842<br>(45%) | 66<br>(93%) | 55<br>(94%) | 36<br>(95%) |
| Scrubber water | 277<br>(15%) | >1<br>(>1%) | >1<br>(>1%) | >1<br>(>1%) |
| Wash down | 24<br>(1%) | >1<br>(>1%) | >1<br>(>1%) | >1<br>(>1%) |
| Bail water (single pass fish unloading) | 726<br>(39%) | 5<br>(7%) | 3<br>(6%) | 2<br>(5%) |

19 summarizes the unit operation waste characteristics for fish meal plants without a solubles unit.

It was concluded that the fish meal production industry should constitute one subcategory with a provision for the July 1, 1977 limitations for plants without a solubles unit operation. The exemplary plants treat, recycle, and evaporate the bailwater and washwater; therefore, other plants with evaporators might be required to modify their facilities and take similar action. The older, smaller plants typically have no existing solubles plant facilities to expand or modify for stickwater or bailwater.

Statistics from plants sampled in these two subcategories are shown in Tables 20 and 21. The tables show the estimated logrithmic-normal mean, the logrithims of the mean and standard deviations, and the 99 percent maximum for each of several selected summary parameters.

Because there is no apparent relationship or trend relating flow ratios, TSS ratios, or BOD5 ratios to production levels (see Figures 22, 23, and 24), it was assumed that the waste loads per unit of production are independent of production level.

## SALMON CANNING

The canning of Pacific salmon was, from the outset of this study, considered to be an important segment of the industry, because of the relatively large waste loadings, high flow rates, and large number of plants. A total of eight plants, in two areas of Alaska and two areas of the Northwest, were investigated; 99 composite samples of unit operations or total effluent were collected.

### Process Description

Figure 25 shows the flow diagram for the typical salmon canning process used in Alaskan and lower Western plants.

Vacuum unloaders, pumps and flumes, high speed elevators and belts and winch-operated live boxes are the common methods of unloading the salmon from the tender holds and transporting them into the cannery. Water used to pump fish from the boats is usually recirculated and discharged after the unloading operation; however, this method is used at a relatively small number of plants.

The salmon are sorted by species and conveyed into holding bins. If the fish are to be held for some time before processing, they are iced or placed in chilled brine.

A butchering machine is used by most plants to accomplish the butchering operation. Many plants in the Northwest manually

## Table 20

### FISH MEAL PROCESS SUMMARY
### OF SELECTED PARAMETERS
### (SOLUBLES PLANT DISCHARGE ONLY)

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION (TON/HR)* | 33.4 | | 20.2 | |
| TIME (HR/DAY)* | 22.1 | | 2.22 | |
| FLOW (L/SEC)* | 242 | | 155 | |
| (GAL/MIN)* | 3840 | | 2470 | |
| FLOW RATIO (L/KKG) | 35000 | 10.5 | 0.046 | 39000 |
| (GAL/TON) | 8400 | 9.04 | 0.046 | 9340 |
| TSS (MG/L) | 26.2 | 3.27 | 0.397 | 66.1 |
| (KG/KKG) | 0.920 | -0.085 | 0.397 | 2.32 |
| BOD-5 (MG/L) | 84.4 | 4.44 | 0.194 | 133 |
| (KG/KKG) | 2.96 | 1.09 | 0.194 | 4.65 |
| GREASE AND OIL (MG/L) | 16.0 | 2.78 | 0.153 | 22.9 |
| (KG/KKG) | 0.562 | -0.577 | 0.153 | 0.802 |
| PH* | 6.07 | | 1.40 | |

PLANTS M2 ,M3 ,M5 ,A2

* NOTE: THE OUTPUTS FOR THESE PARAMETERS ARE THE NORMAL (UNWEIGHTED) MEAN AND STANDARD DEVIATION, RESPECTIVELY

## Table 21

### FISH MEAL PROCESS SUMMARY OF SELECTED PARAMETERS (WITHOUT SOLUBLES PLANT)

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION (TON/HR)* | 7.60 | | 1.46 | |
| TIME (HR/DAY)* | 15.7 | | 11.8 | |
| FLOW (L/SEC)* | 13.1 | | 12.9 | |
| (GAL/MIN)* | 208 | | 204 | |
| FLOW RATIO (L/KKG) | 1900 | 7.55 | 0.120 | 2510 |
| (GAL/TON) | 456 | 6.12 | 0.120 | 602 |
| TSS (MG/L) | 18300 | 9.81 | 0.273 | 34500 |
| (KG/KKG) | 34.8 | 3.55 | 0.273 | 65.6 |
| BOD-5 (MG/L) | 32700 | 10.4 | 0.144 | 45700 |
| (KG/KKG) | 62.2 | 4.13 | 0.144 | 87.0 |
| GREASE AND OIL (MG/L) | 12000 | 9.39 | 0.534 | 41600 |
| (KG/KKG) | 22.8 | 3.13 | 0.534 | 79.1 |
| PH* | 6.80 | | 0.026 | |

PLANTS A1 ,A3

* NOTE: THE OUTPUTS FOR THESE PARAMETERS
ARE THE NORMAL (UNWEIGHTED) MEAN
AND STANDARD DEVIATION, RESPECTIVELY

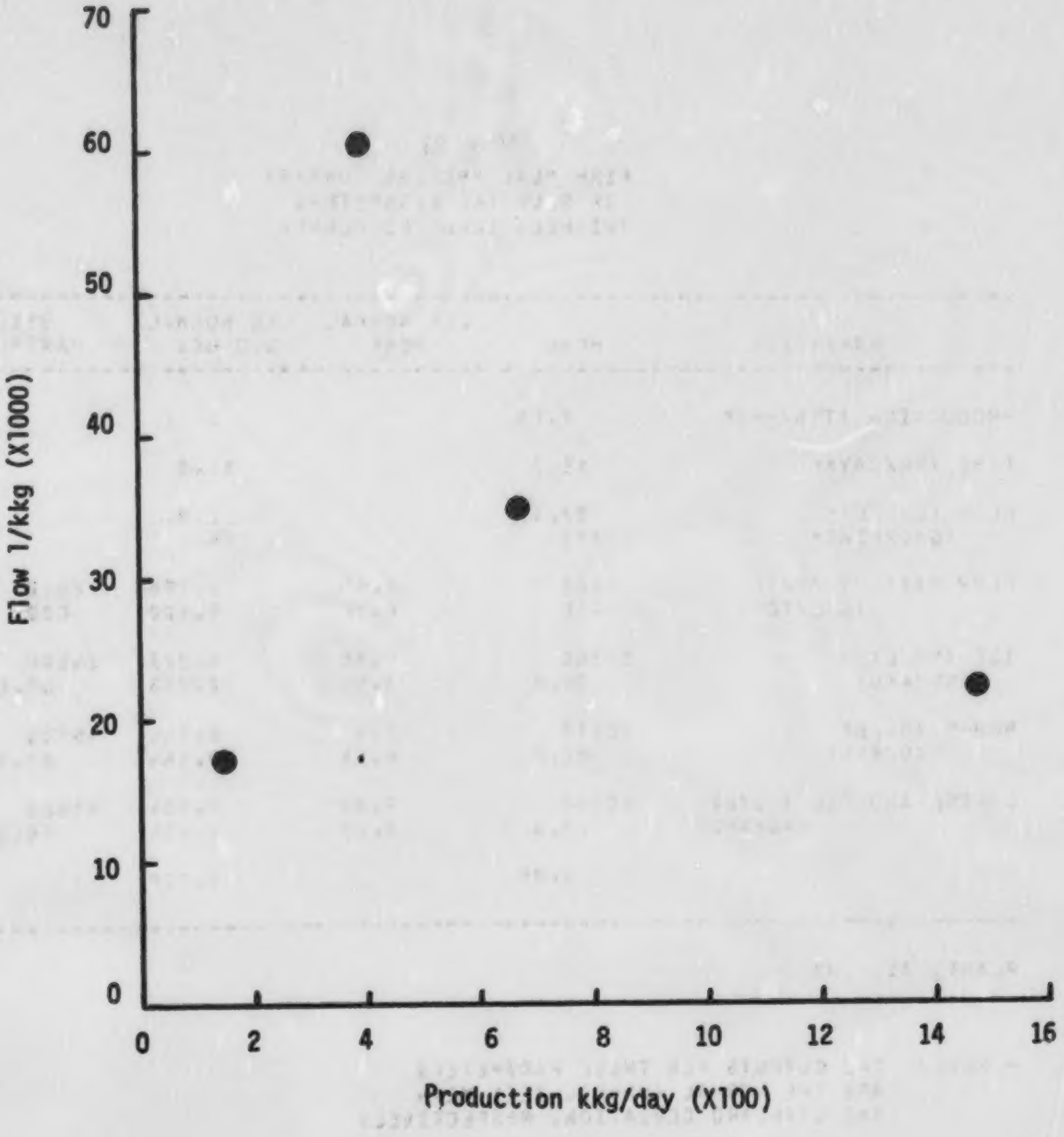


Figure 22

Fish meal flow ratios versus production level

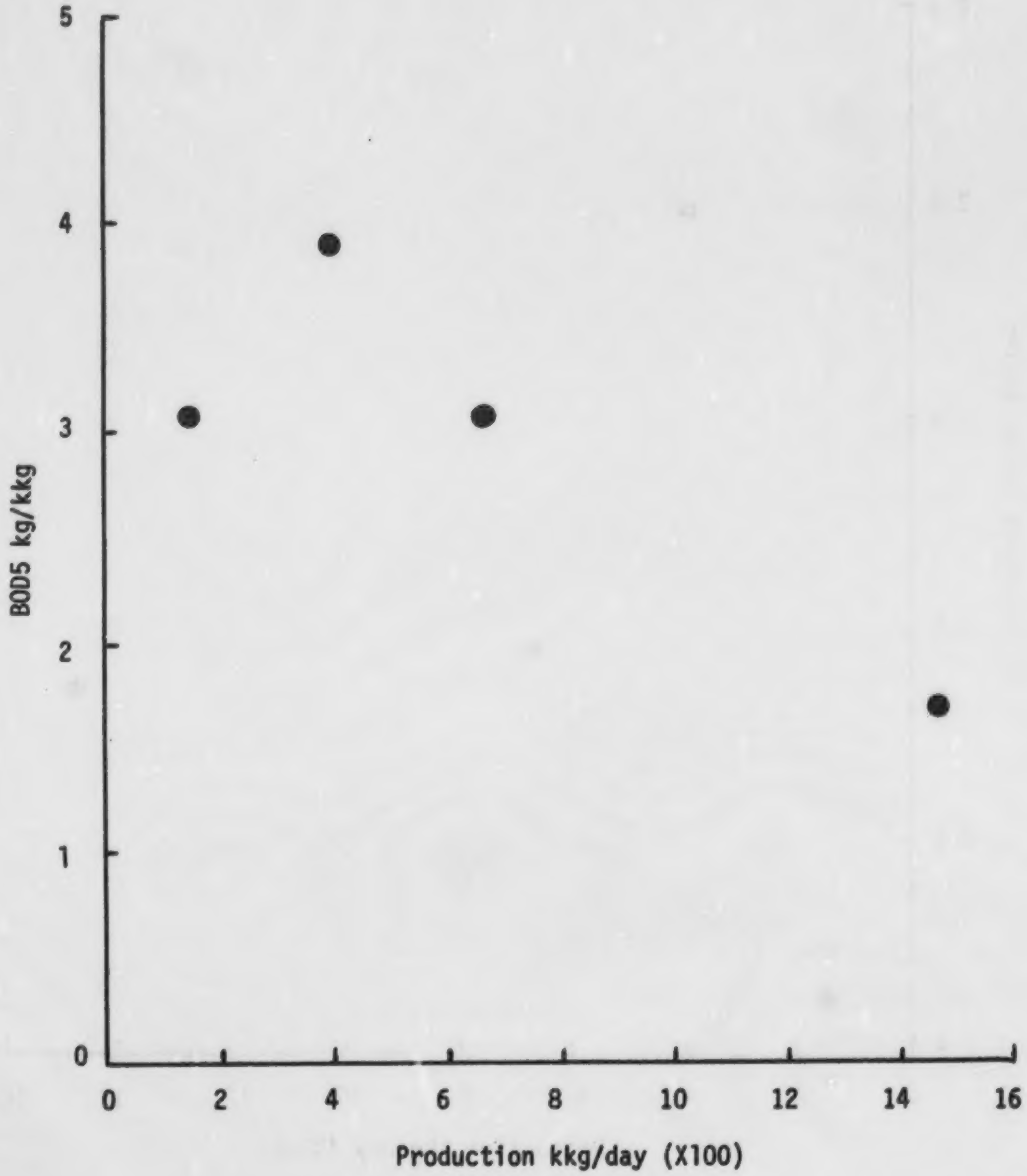


Figure 23

Fish meal BOD5 ratios versus production level

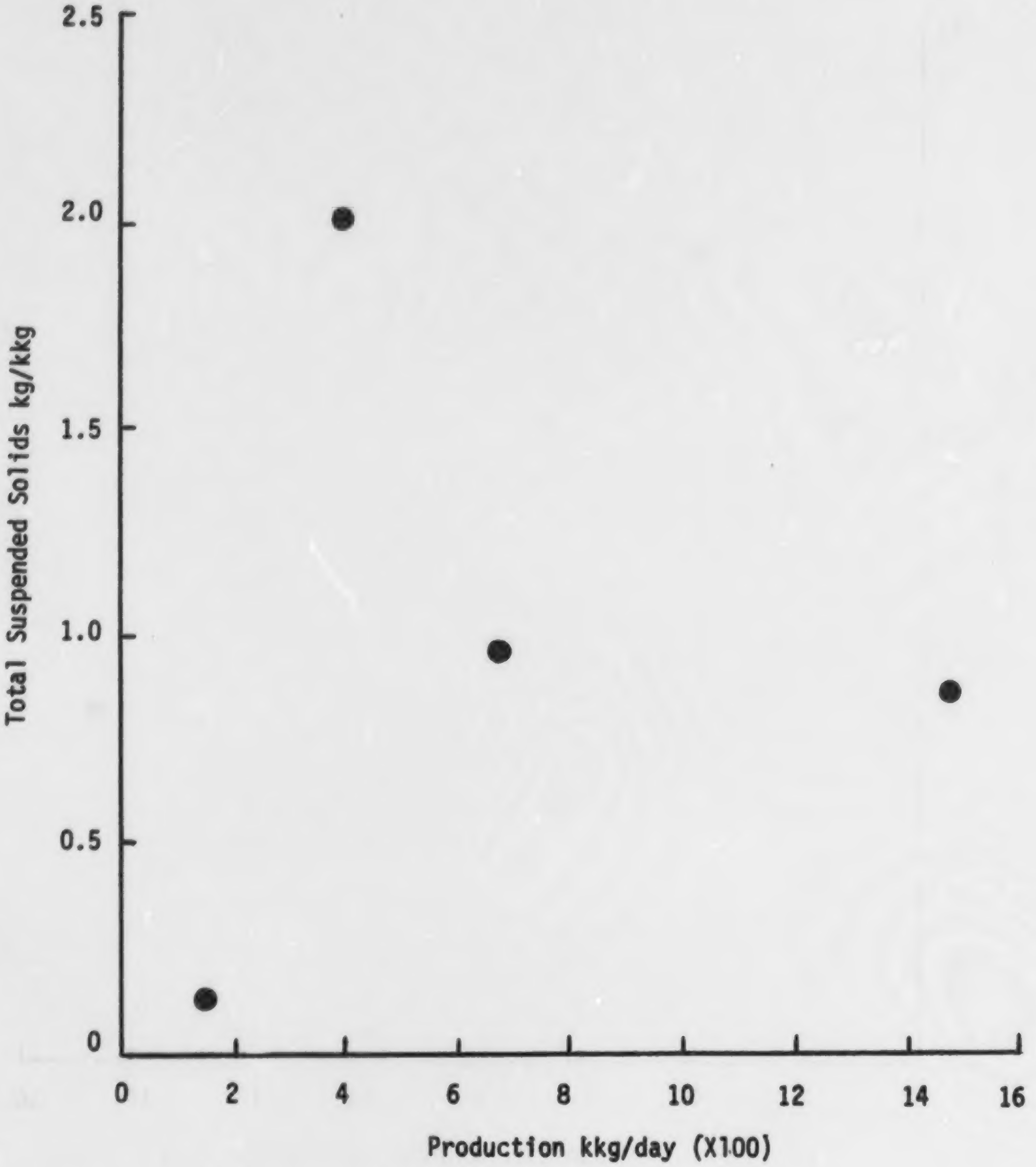


Figure 24

Fish meal total suspended solids ratios versus production level

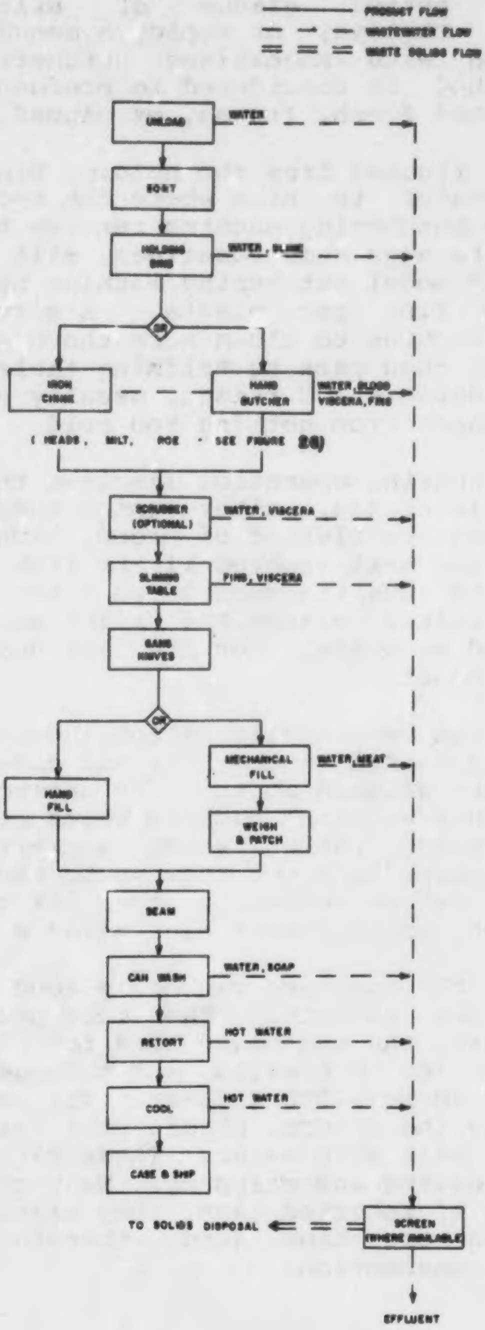

PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
UNLOAD
WATER
SORT
HOLDING BINS
WATER, SLIME
OR
IRON CHINK
HAND BUTCHER
WATER, BLOOD VISCERA, FINS
( HEADS, MILT, ROE - SEE FIGURE 26)
SCRUBBER (OPTIONAL)
WATER, VISCERA
SLIMING TABLE
FINS, VISCERA
GANG KNIVES
OR
MECHANICAL FILL
WATER, MEAT
HAND FILL
WEIGH & PATCH
SEAM
CAN WASH
WATER, SOAP
RETORT
HOT WATER
COOL
HOT WATER
CASE & SHIP
TO SOLIDS DISPOSAL
SCREEN (WHERE AVAILABLE)
EFFLUENT

**Figure 25** **Typical salmon canning process.**

butcher the better grades of silvers, chinooks, and (occasionally) sockeye, or employ a manual butchering operation in conjunction with mechanized butchering, since the more laborious method is considered to produce a finer product. The fish are marketed fresh, frozen, or canned, depending on demand.

The salmon are flushed from the holding bins and transported by flume or elevator to bins where the mechanical eviscerator is employed. The butchering machine removes the heads, tails, fins, and viscera; the eggs and, sometimes, milt are manually separated later. The "K" model butchering machine has a maximum capacity of about 120 fish per minute. A scrubber is sometimes used following the machine to clean more thoroughly the coeloms of the fish. The fish then pass to "sliming tables," where each fish is inspected for defects and rinsed, usually with warm water to keep the worker's hands from getting too cold.

The manual butchering operation involves three steps. The fish are first eviscerated, after which they are passed to another table where they are cleaned of blood, kidneys and slime. The head and fins are next removed if the fish are to be canned. The cleaned fish are then transported to a set of gang knives. These knives are located within the filler machine for the one-half-pound lines and separately for the one-quarter-pound lines and hand-packed product.

All can sizes can be manually filled; however, most of the salmon is mechanically packed in one-half and one-pound cans. The hand-packed cans are weighed as they are packed. Mechanically packed cans go through a weighing machine which rejects the light-weight cans onto a "patch table" where workers add patch material (supplemental meat) to bring them up to their proper weight. The workers also remove bones and other material that may interfere with the seamer, which closes cans using a vacuum pump or steam.

After seaming, the cans are washed, placed in cooler trays, and loaded into the retorts. The four-pound cans are cooked for about four hours, the one-pound cans for 90 minutes, the one-half-pound cans for 60 minutes, and the one-quarterpound cans for 40 minutes at about 120°C (250°F). The cans are water cooled by either flooding the retort, placing the cans in a water bath, or spraying the cans with water. These cans are then further air-cooled before casing and shipping. Many canneries do not employ water cooling of retorted cans; they simply air-cool them. This method requires more time (and, therefore, more space), but reduces water consumption.

## By-Product Operations

Further milt, roe, and head processing is an integral part of many salmon canning plants. Figure 26 shows the typical operations involved. Salmon milt is sometimes frozen and shipped to Japan for further processing. The roe is agitated in a saturated salt brine before being packed in boxes. Salt is added to each layer of eggs to aid in the curing process. Some eggs are also sold for bait.

The heads are handled in a variety of ways. Some plants, particularly those in Bristol Bay and Puget Sound, render the heads for oil. Fish oil is then added to cans to improve the quality of the finished product. Other plants grind and freeze the heads, which are later processed for animal food. Whole heads are sometimes frozen and used for bait or pet food. Some plants grind the heads with the other solid wastes and discharge them to the receiving waters. Most plants in the Northwest send recoverable wastes to rendering plants for fish meal production.

## Subcategorization Rationale

Since the salmon canning process is essentially the same from plant to plant, the only major factor which may prompt further subcategorization is geographic location.

The salmon canning industry was subcategorized into Alaska and Western regions because of the much greater costs and treatment problems encountered in Alaska. Furthermore, due to the large size range of the industry in both areas, the Alaska industry was divided into three sizes and the Western industry into two sizes for the purpose of costing control and treatment technologies. Figures 27 and 28 depict the size distributions of the Alaska and Western salmon canning plants, respectively (19). The information is expressed in the form of histograms or probability density functions. The vertical axis represents the number of plants whose output falls in the range shown on the horizontal axis, which is expressed as the average annual output in cases from 1966 to 1970; for example, the data show that 15 plants in Alaska produced between 0 and 20,000 cases annually. The histograms are skewed to the right in a manner similar to a theoretical log-normal density function. There is no obvious, distinct grouping of plant sizes; however, the following divisions were established to develop criteria which would adequately cover the range:

Alaska salmon canning--large: greater than 80,000 cases annually;

Alaska salmon canning--medium: 40,000 to 80,000 cases annually;

Alaska salmon canning--small: fewer than 40,000 cases annually;

Western salmon canning--large: greater than 20,000 cases annually; and

Western salmon canning--small: 20,000

cases annually or fewer.

Figure 29 shows a summary plot of the wastewater characteristics of three salmon canning plants in Alaska (CSN2, CSN3, CSN4) and four plants in the Northwest (CSN5, CSN6, CSN7, and CSN8). CS6M represents the manual butchering operation at plant CSN6. Codes CS7H and CS8H represent historical data from the same plants as CSN7 and CSN8, respectively. Two of the Alaskan plants sampled, CSN2 and CSN4, are in the "small" range (less than 40,000 cases), and one, CSN3 is in the "medium" range (40,000-80,000 cases). All of the plants sampled in the Northwest are in the large range (over 20,000 cases).

It was noted that, in general, the waste loads from the plants in Alaska were greater than those from the Pacific Northwest plants. The main reason for this is that one Northwest plant (CSN5) did all butchering by hand and two other Northwest plants (CSN6 and CSN7) practiced a high percentage of manual butchering during the sampling period, using the butchering machine only when large quantities of fish arrived. The three salmon plants in Alaska also ground their solids before discharge, which increased the waste load. The waste load at CSN3 appears to have been higher than average; however, this may have been due to the fact that samples were taken from a sump where solids accumulated over the sampling period. The historical information from plant CS8H was obtained during a high production period when the butchering machine was being used extensively. This data appears to be lower and may be attributable to plant modifications accomplished after the historical data was collected.

Table 22 shows summary statistics of the waste loads from all the plants sampled which used the butchering machine exclusively (CSN2, CSN3, CSN4, CSN8). The flow ratio was not included for CSN8, as it was not considered to be typical because of flows through butchering machines which were not processing fish. These data provided the base which was used as the typical raw waste load from salmon canning processes in both Alaska and the West Coast. Because there is no apparent relationship or trend relating flow ratios, TSS ratios, or BOD5 ratios to production levels (See Figures 30,31, and 32), it was assumed that the waste loads per unit of production are independent of production level.

The canning operations in the Northwest which hand butcher are included with the fresh/frozen salmon subcategory, which is discussed next, since the unit operations are similar except for the canning operation, which does not increase the load by a significant amount.

## FRESH AND FROZEN SALMON

The processing of Pacific salmon as a fresh or frozen commodity was considered to have smaller waste loads and wastewater flows than the canning segment of the salmon industry. A total of six

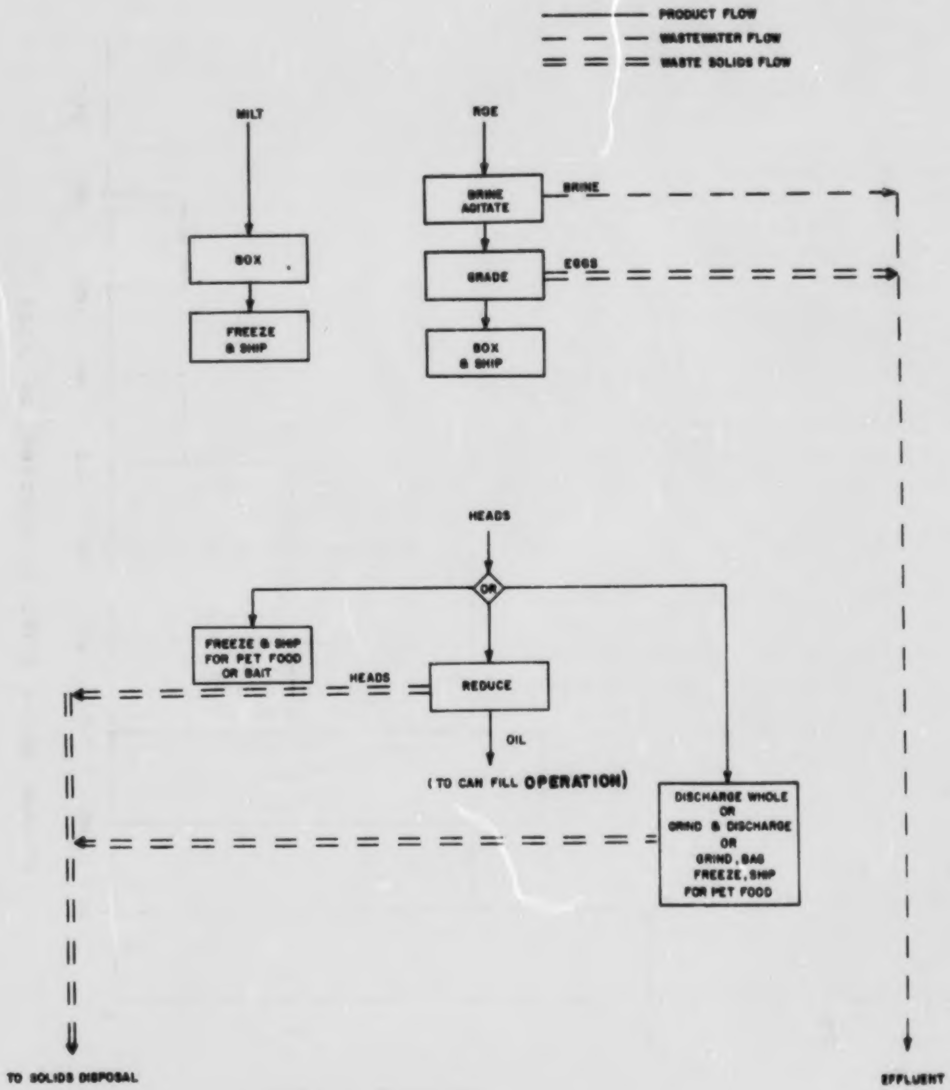

PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
MILT
BOX
FREEZE & SHIP
ROE
BRINE AGITATE
BRINE
GRADE
EGGS
BOX & SHIP
HEADS
OR
FREEZE & SHIP FOR PET FOOD OR BAIT
HEADS
REDUCE
OIL
(TO CAN FILL OPERATION)
DISCHARGE WHOLE OR GRIND & DISCHARGE OR GRIND, BAG FREEZE, SHIP FOR PET FOOD
TO SOLIDS DISPOSAL
EFFLUENT

Figure 26 . Typical salmon by-product operations.

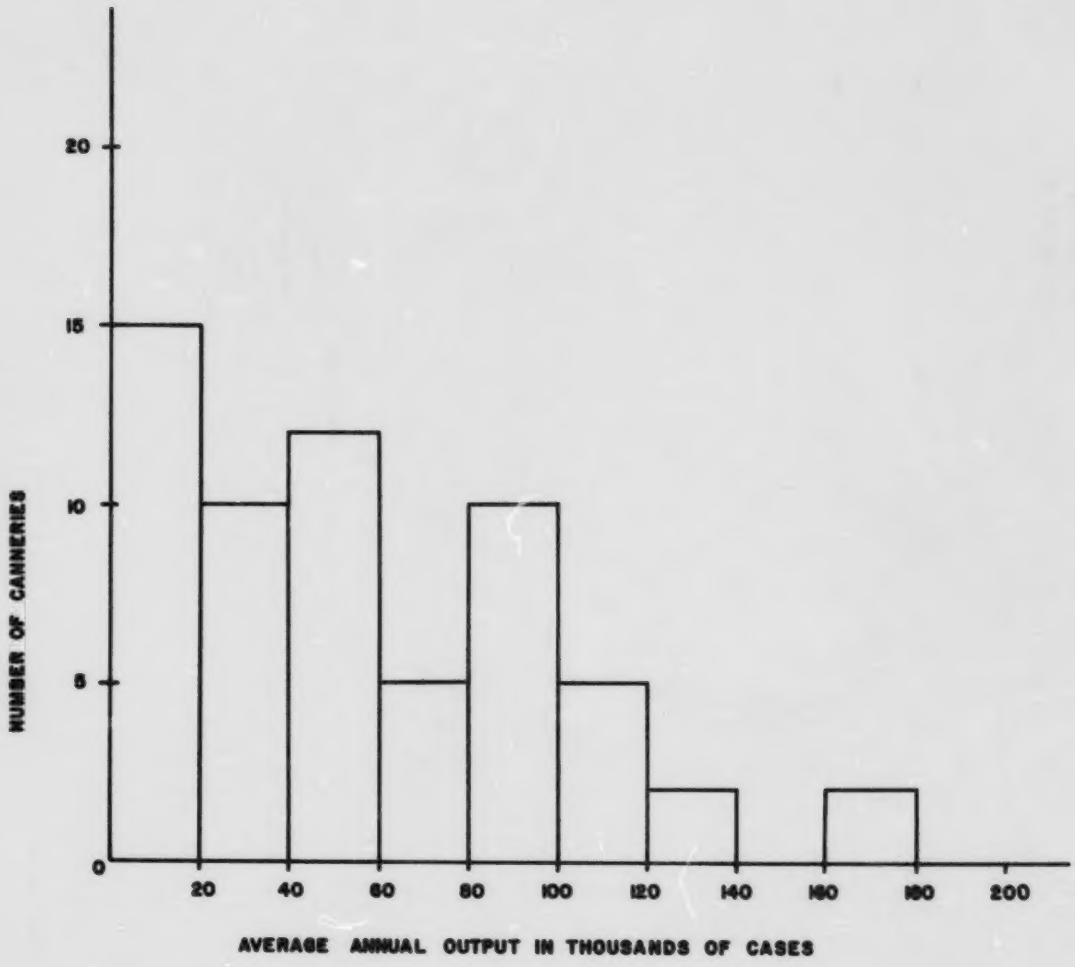


Figure 27. Alaska salmon cannery size distribution.

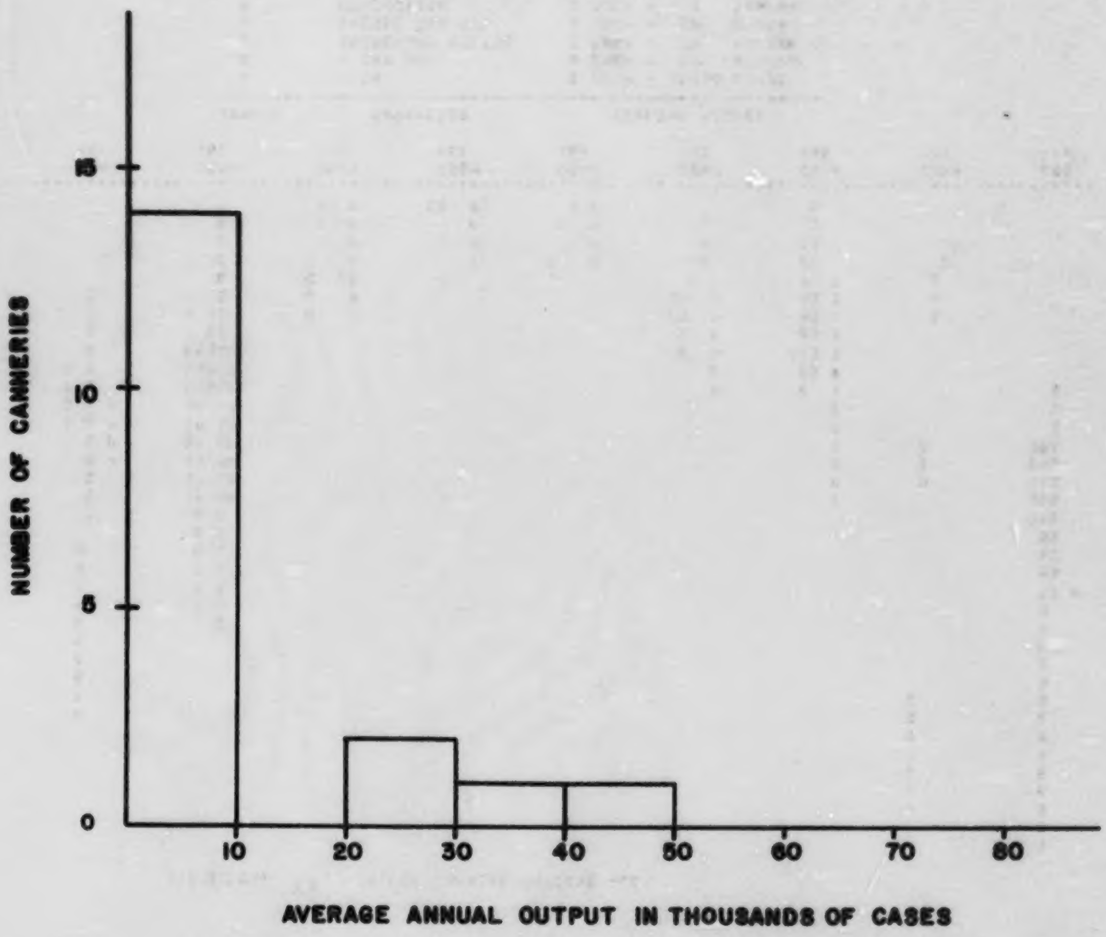
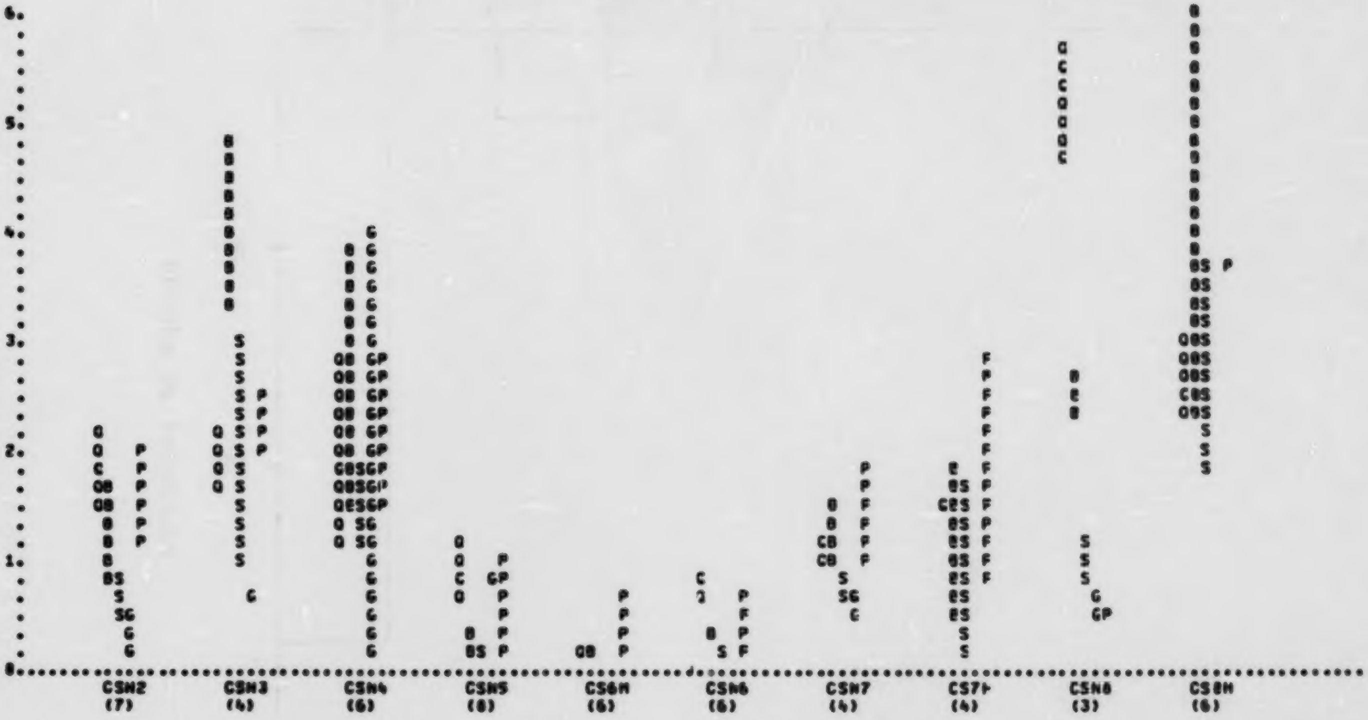


Figure 28 . Western salmon cannery size distribution.

Figure 29. SALMON CANNING PROCESS PLOT.



| SYMBOL | PARAMETER | SCALING FACTOR |
|---|---|---|
| Q | FLOW | 1 INCH = 10000 L/KKG |
| B | 5 DAY BOD | 1 INCH = 20 KG/KKG |
| S | SUSPENDED SOLIDS | 1 INCH = 20 KG/KKG |
| G | GREASE AND OIL | 1 INCH = 10 KG/KKG |
| P | PRODUCTION | 1 INCH = 2 TON/HR |

## Table 22

### MECHANICALLY BUTCHERED SALMON
### PROCESS SUMMARY
### OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION (TON/HR)* | 3.32 | | 1.67 | |
| TIME (HR/DAY)* | 6.87 | | 1.05 | |
| FLOW (L/SEC)* | 17.2 | | 5.09 | |
| (GAL/MIN)* | 274 | | 80.8 | |
| FLOW RATIO (L/KKG) | 10500 | 9.03 | 0.091 | 22000 |
| (GAL/TON) | 4440 | 8.40 | 0.091 | 5470 |
| TSS (MG/L) | 1100 | 7.00 | 0.120 | 1400 |
| (KG/KKG) | 20.3 | 3.01 | 0.120 | 27.3 |
| BOD-5 (MG/L) | 2750 | 7.92 | 0.125 | 3670 |
| (KG/KKG) | 50.8 | 3.93 | 0.125 | 67.9 |
| GREASE AND OIL (MG/L) | 351 | 5.86 | 0.605 | 1430 |
| (KG/KKG) | 6.49 | 1.87 | 0.605 | 26.5 |
| PH* | 6.71 | | 0.173 | |

PLANTS CSN2,CSN3,CSN4,CSN8

* NOTE: THE OUTPUTS FOR THESE PARAMETERS
ARE THE NORMAL (UNWEIGHTED) MEAN
AND STANDARD DEVIATION, RESPECTIVELY

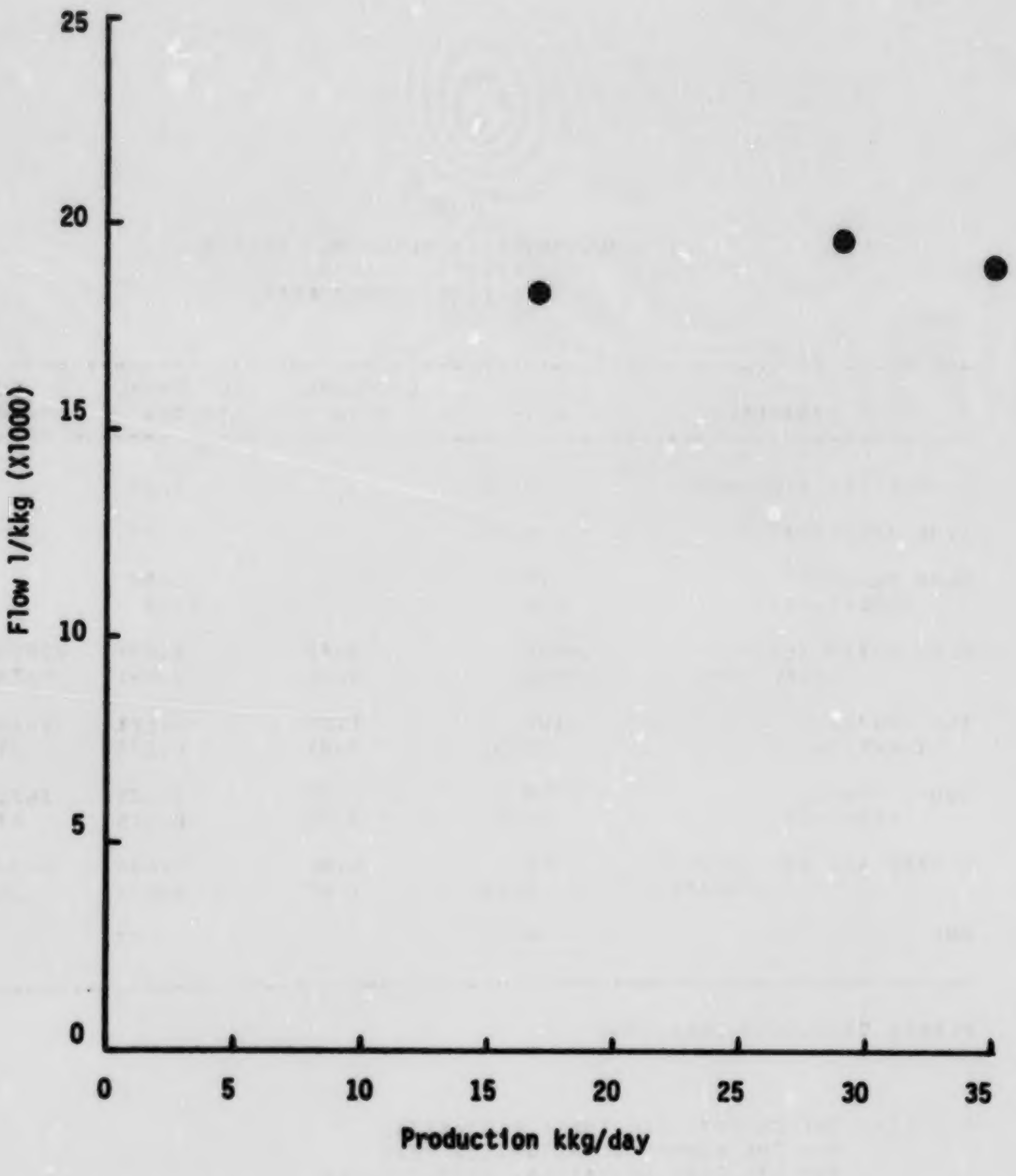


Figure 30

Mechanized salmon flow ratios versus production level

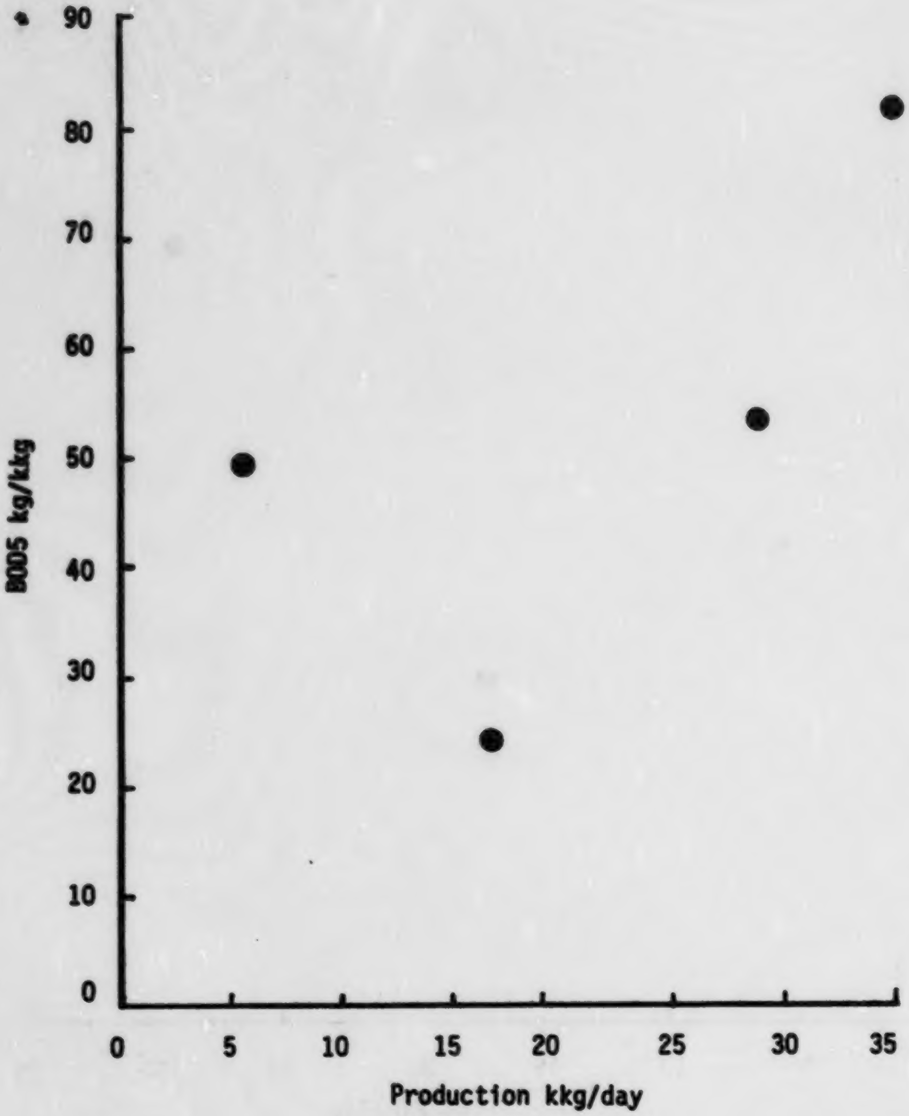


Figure 31

Mechanized salmon BOD5 ratios versus production level

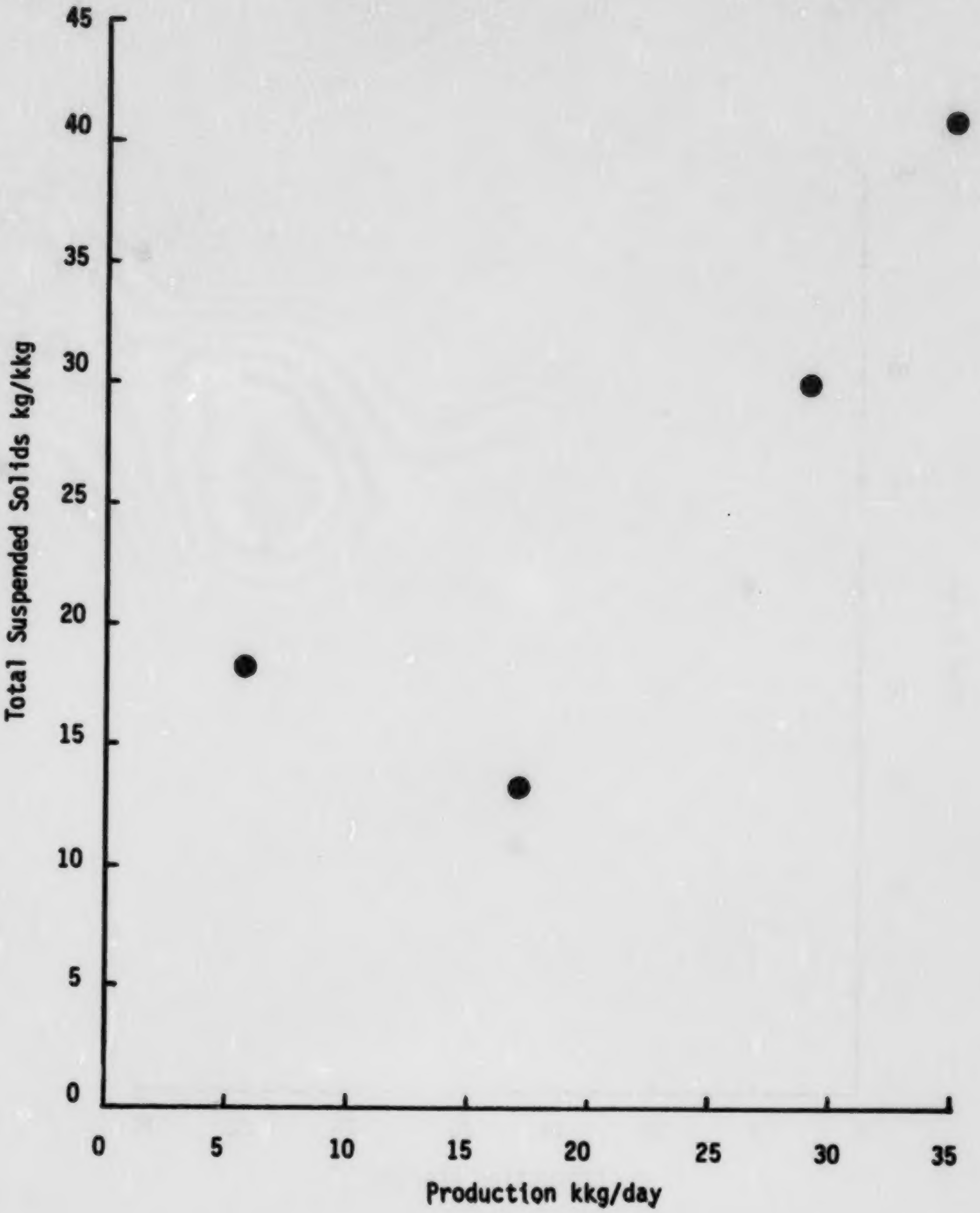


Figure 32
Mechanized salmon total suspended solids versus production level

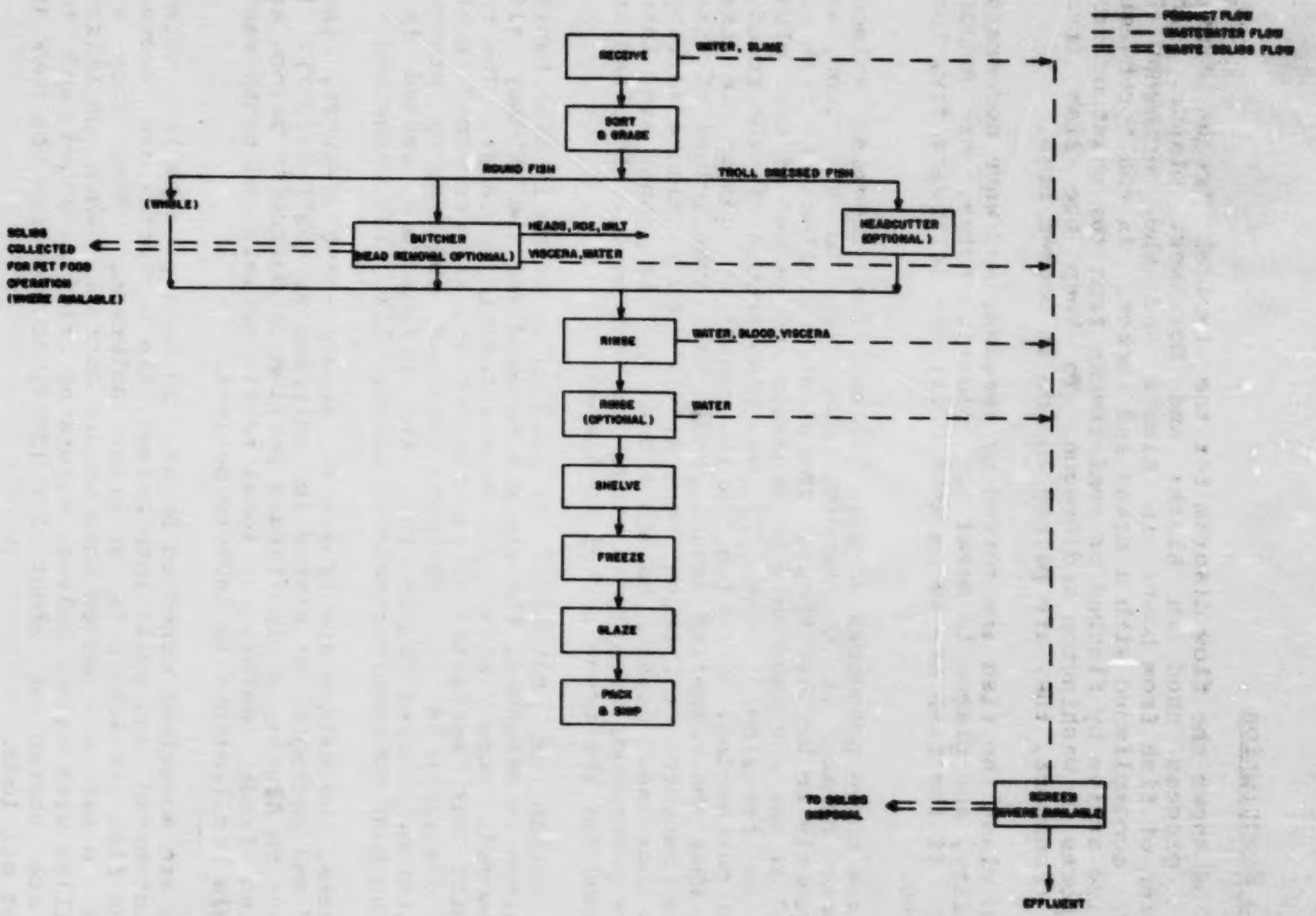

PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
RECEIVE
WATER, SLIME
SORT & GRADE
ROUND FISH
TROLL DRESSED FISH
(WHOLE)
BUTCHER (HEAD REMOVAL OPTIONAL)
HEADS, ROE, MILT
VISCERA, WATER
HEADCUTTER (OPTIONAL)
SOLIDS COLLECTED FOR PET FOOD OPERATION (WHERE AVAILABLE)
RINSE
WATER, BLOOD, VISCERA
RINSE (OPTIONAL)
WATER
SHELVE
FREEZE
GLAZE
PACK & SHIP
SCREEN (WHERE AVAILABLE)
TO SOLIDS DISPOSAL
EFFLUENT

Figure 38 . Typical fresh/frozen salmon process.

plants in three areas of Alaska and one area of the Northwest were investigated; 77 unit operation and effluent composite samples were collected.

## Process Description

Figure 33 shows the flow diagram for the typical fresh/ frozen salmon process used in Alaska and Northwest plants. The unloading of fish from boats in Alaska and the Northwest is usually accomplished with a crane and bucket. In the Northwest, fish also arrive by flatbed or semi-trucks from the coast or from other ports in Washington and Oregon. To keep the fish fresh during transport, they are packed in ice in wooden bins.

At the plant the fish are sorted by species, and when necessary, by quality, and placed in metal or plastic totes, or gondola carts. If the fish are to be kept until the following day, they are iced.

There are three processes used in Alaska for freezing salmon. The most common is to receive the fish in the round, and subsequently to butcher them in the plant. Troll-caught fish are dressed at sea and need only be beheaded and washed at the plant prior to freezing. Some fish are also frozen "in the round," without butchering. Freezing "in the round" is common in peak years, when the canneries cannot handle the large volume of fish, and is expected to become more widely used in Alaska as labor prices increase. Alaskan salmon frozen in this manner are later further processed, usually in Oregon or Washington. Few fish are processed for the fresh market in Alaska.

Round salmon are butchered by hand on an assembly line basis. The salmon is beheaded, the viscera removed and the kidney slit and removed. Some plants use a semi-automatic beheader. The roe and milt are separated from the viscera and processed in the manner described in the "Salmon Canning" subcategory process description. After butchering, the salmon are washed in a cleaning tank to remove remaining blood, slime, and parasites.

In Alaska, the salmon are frozen at about -51°C (-60°F), then glazed and packaged, or stored for shipping at -23°C (-10°F). In contrast to Alaska, a significant portion of Northwest salmon are marketed fresh, mainly to local retail outlets and restaurants and (via air freight) to Eastern outlets.

Salmon are sometimes cured in brine. In this process the salmon are butchered and split into halves, the backbones are removed, and the fish are washed in a brine solution. Then they are dipped in salt and packed into wooden barrels. When the barrels are filled with salmon halves, saturated brine is added and the fish are stored at about 2°C (36°F) to preserve the pack and prevent oil loss.

## Subcategorization Rationale

Since the fresh/frozen salmon process is essentially the same throughout the industry, geographic location was considered to be the only major factor affecting subcategorization.

It was decided that the fresh/frozen salmon industry be subcategorized into "Alaska" and "West Coast" regions because of the greater costs and more serious treatment problems encountered in Alaska. The size range of the industry is significant in both regions; however, it is not as great as the range for salmon canning.

Information on the size range of the industry in terms of annual production is limited. Table 23 summarizes data obtained from a study conducted by the Municipality of Metropolitan Seattle (20) involving Northwest fresh/frozen salmon plants.

For the purpose of costing control and treatment technologies, Table 24 estimates the daily peak production rates for Alaskan fresh/frozen salmon plants. Based on these figures and observations made during the plant investigations, the dividing line between large and small Alaskan and Northwest fresh/frozen salmon plants was placed at 2370 kkg (2500 tons) of raw product processed annually.

Figure 34 is a summary plot of the wastewater characteristics of four fresh/frozen salmon operations in Alaska (FS1, FS2, FST1, FST2) and three operations in the Northwest (FS3, FS4, FST3). The code FS represents processes which butcher round salmon, while the code FST represents the processing of troll-dressed salmon, which have been eviscerated at sea. The four processes in Alaska (FS1, FST1, FS2, FST2) fall into the "large" range, while the three Northwest processes (FS3, FST3, FS4) are in the "small" range.

It can be seen that the waste loads from the troll-dressed processes were lower than those from the round processes and that the waste loads from the Alaskan plants seem to have been slightly higher than those from the Northwest plants. The waste loads from all these operations, however, are relatively low, with BOD's less than 3 kg/kkg.

Since the unit operations, where most of the waste is generated, are similar for either the hand butcher fresh/frozen process or the hand butcher canning process, they are included in one subcategory. The average waste loads from the round fresh/frozen processes (FS1, FS2, FS3, FS4) and from the hand butcher canning process (CSN5, CS6M) are used to characterize both segments of the industry.

It would not be efficient to further subdivide the industry into "round," "troll dressed" and hand butcher canning processes with the corresponding regulations and enforcement efforts required.

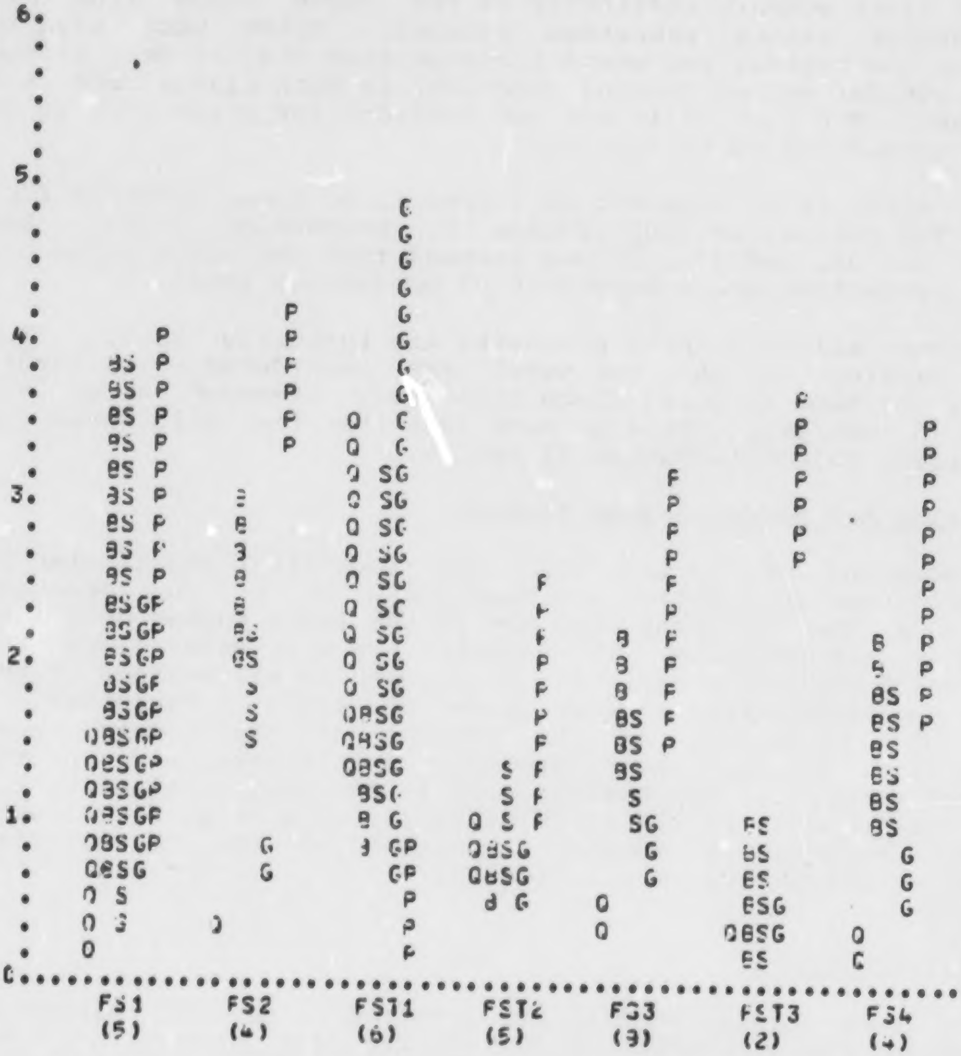
Table 23 . Annual production of Northwest fresh/frozen salmon.

| Plant Number | Raw Product Processed Annually (kkg) | Raw Product Processed Annually (tons) |
|---|---|---|
| 1 | 360 | 400 |
| 2 | 680 | 750 |
| 3 | 725 | 800 |
| 4 | 1815 | 2000 |
| 5 | 2720 | 3000 |
| 6 | 4535 | 5000 |

Table 24 . Daily peak production rates of Alaska fresh/frozen salmon plants (9)

| Size | Daily Peak Production Rate (kkg) | Daily Peak Production Rate (tons) |
|---|---|---|
| Large | 80-110 | 90-120 |
| Medium | 45-70 | 50-75 |
| Small | 27-45 | 30-50 |

Figure 34. FRESH/FROZEN SALMON PROCESS PLOT.



| SYMBOL | PARAMETER | SCALING FACTOR |
|---|---|---|
| O | FLOW | 1 INCH = 10000 L/KKG |
| B | 5 DAY BOD | 1 INCH = 1 KG/KKG |
| S | SUSPENDED SOLIDS | 1 INCH = 0.5 KG/KKG |
| G | GREASE & OIL | 1 INCH = 0.2 KG/KKG |
| P | PRODUCTION | 1 INCH = 1 TON/HR |

The slight advantage of those plants processing mostly troll-dressed fish was considered to be of little importance, since the waste loads from any of these processes are relatively low. Table 25 lists summary statistics of the waste loads from all hand butcher salmon processes sampled. These were used to determine the typical raw waste loadings from fresh/frozen salmon or hand butcher salmon canning processes in both Alaska and the West Coast. The flow ratio was not included for plant FS1, as it was not considered to be typical.

Because there is no apparent relationship or trend relating flow ratios, TSS ratios, or $BOD_5$ ratios to production levels (See Figures 35, 36, and 37), it was assumed that the waste loads per unit of production are independent of production level.

Hand butcher salmon canning processes are typically small. The plants sampled in the Northwest are considered to be large; however, the hand butcher salmon line only averaged about 4.5 kkg/day (5 tons/day). This is much less than the ratio shown for fresh/frozen salmon in Tables 23 and 24.

## BOTTOM FISH AND MISCELLANEOUS FINFISH

The processing of bottom fish (or groundfish) and finfish as fresh or frozen commodities was considered to be an important segment of the industry because of the large number of plants engaged in this activity. The industry has wastewater flows and loads which are quite variable, is located in all regions of the country and encompasses a large range of sizes. Therefore, a total of 20 plants in six regions of the country were investigated. This included three plants in Alaska, six in the Northwest, four in New England, two in the Middle Atlantic, two in the Gulf, and three plants in California. A total of 207 unit operations or effluent composite samples of the bottom fish industry's wastewaters were collected.

### Process Description

Although many species of fish are involved in several regions of the country, the processing of bottom fish (or groundfish) and finfish primarily involves the preparation of fillets or whole fish for the fresh or frozen market. Most fillets are frozen in blocks and processed later as fish sticks or portions. Whole fish processing is also important for some species such as halibut and the larger groundfish. The amount of whole fish processing varies with the species of fish, the region, and market demands.

The processing descriptions below are organized by region, since the species involved and the processing methods employed are relatively uniform within each.

## Table 25

### HAND BUTCHERED SALMON
### PROCESS SUMMARY
### OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION (TON/HR)* | 1.94 | | 1.19 | |
| TIME (HR/DAY)* | 6.34 | | 1.00 | |
| FLOW (L/SEC)* | 2.36 | | 1.41 | |
| (GAL/MIN)* | 37.5 | | 22.3 | |
| FLOW RATIO (L/KKG) | 3960 | 6.28 | 0.079 | 4750 |
| (GAL/TON) | 976 | 6.88 | 0.102 | 1240 |
| TSS (MG/L) | 305 | 5.72 | 0.147 | 429 |
| (KG/KKG) | 1.21 | 0.188 | 0.147 | 1.70 |
| BOD-5 (MG/L) | 534 | 6.28 | 0.108 | 686 |
| (KG/KKG) | 2.11 | 0.749 | 0.108 | 2.72 |
| GREASE AND OIL (MG/L) | 38.6 | 3.65 | 0.119 | 50.8 |
| (KG/KKG) | 0.153 | -1.88 | 0.118 | 0.202 |
| PH* | 6.73 | | 0.314 | |

PLANTS CSN5,CS64,FS1 ,FS2 ,FS3 ,FS4

* NOTE: THE OUTPUTS FOR THESE PARAMETERS
ARE THE NORMAL (UNWEIGHTED) MEAN
AND STANDARD DEVIATION, RESPECTIVELY

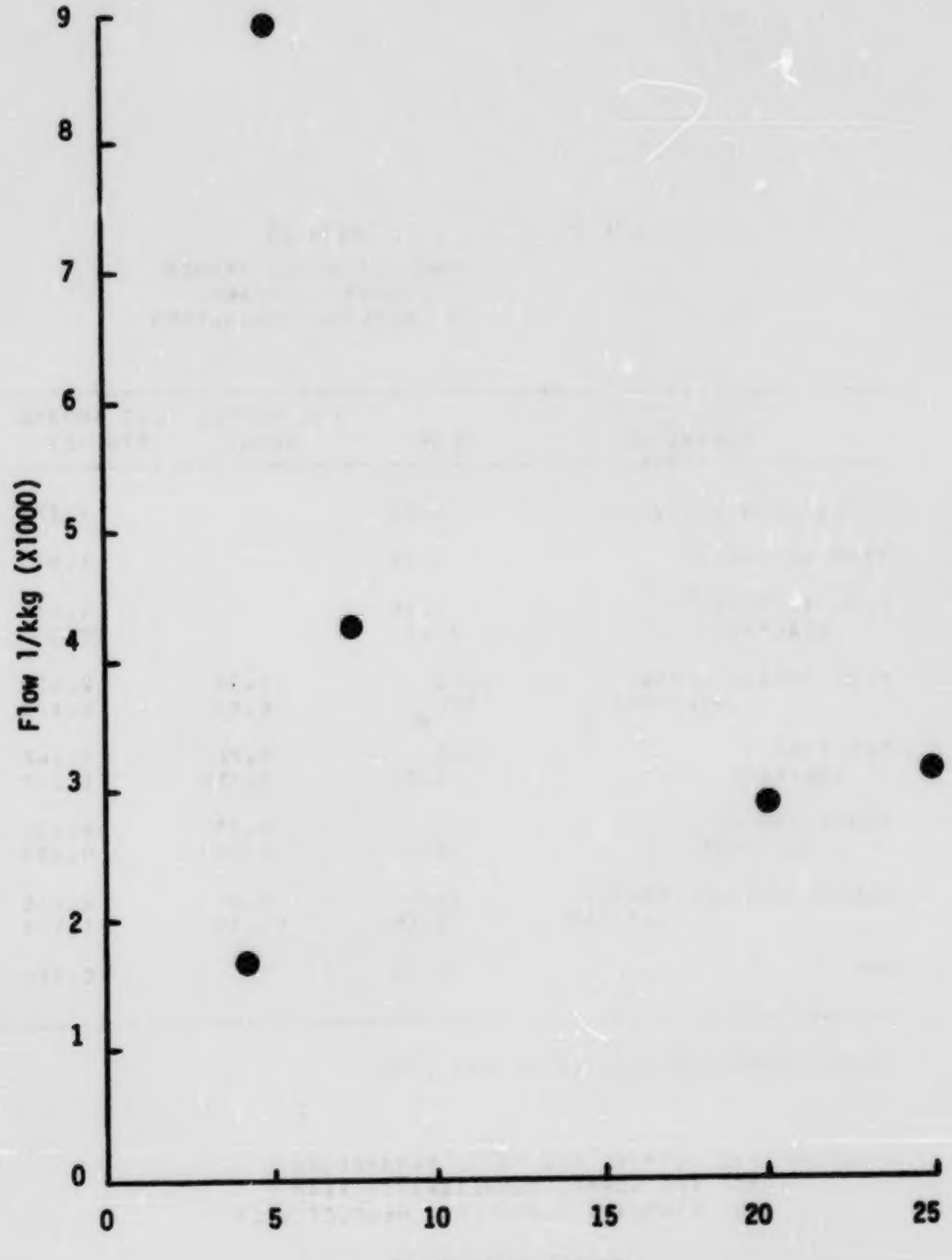


Figure 35
Hand-butchered salmon flow ratios
versus production level

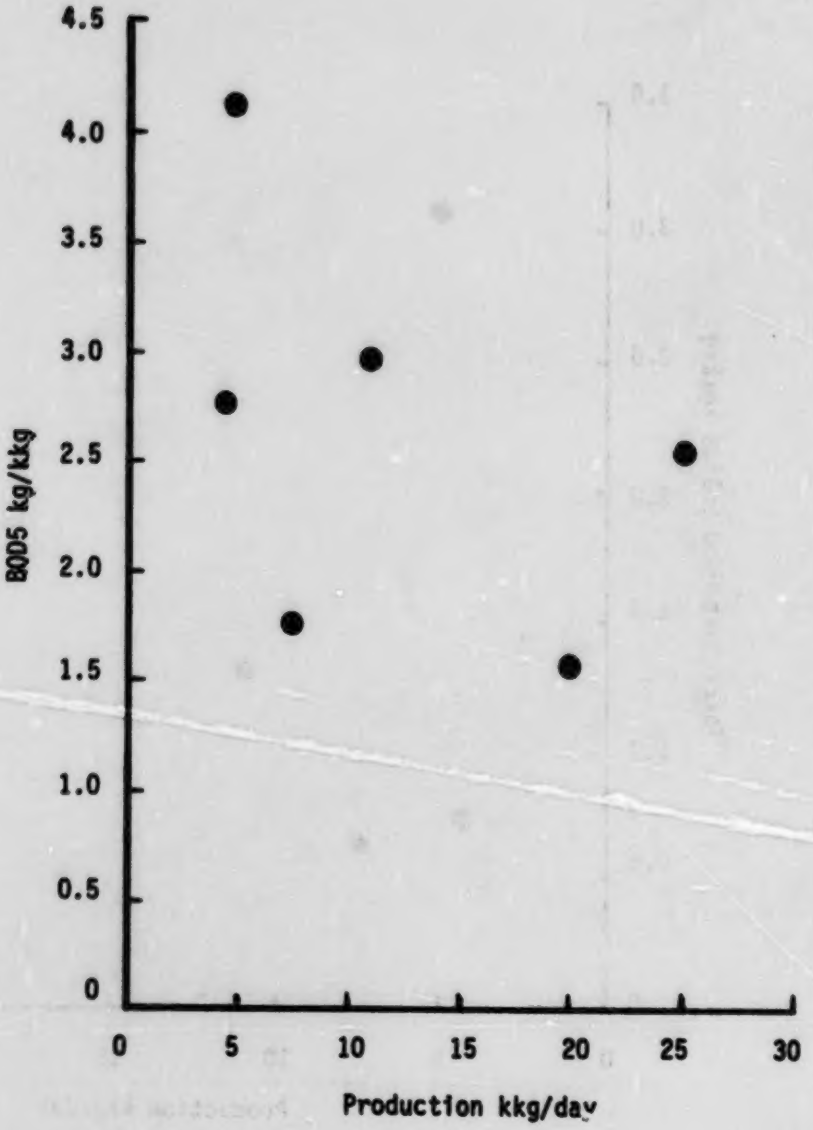


Figure 36
Hand-butchered salmon BOD5 ratios
versus production level

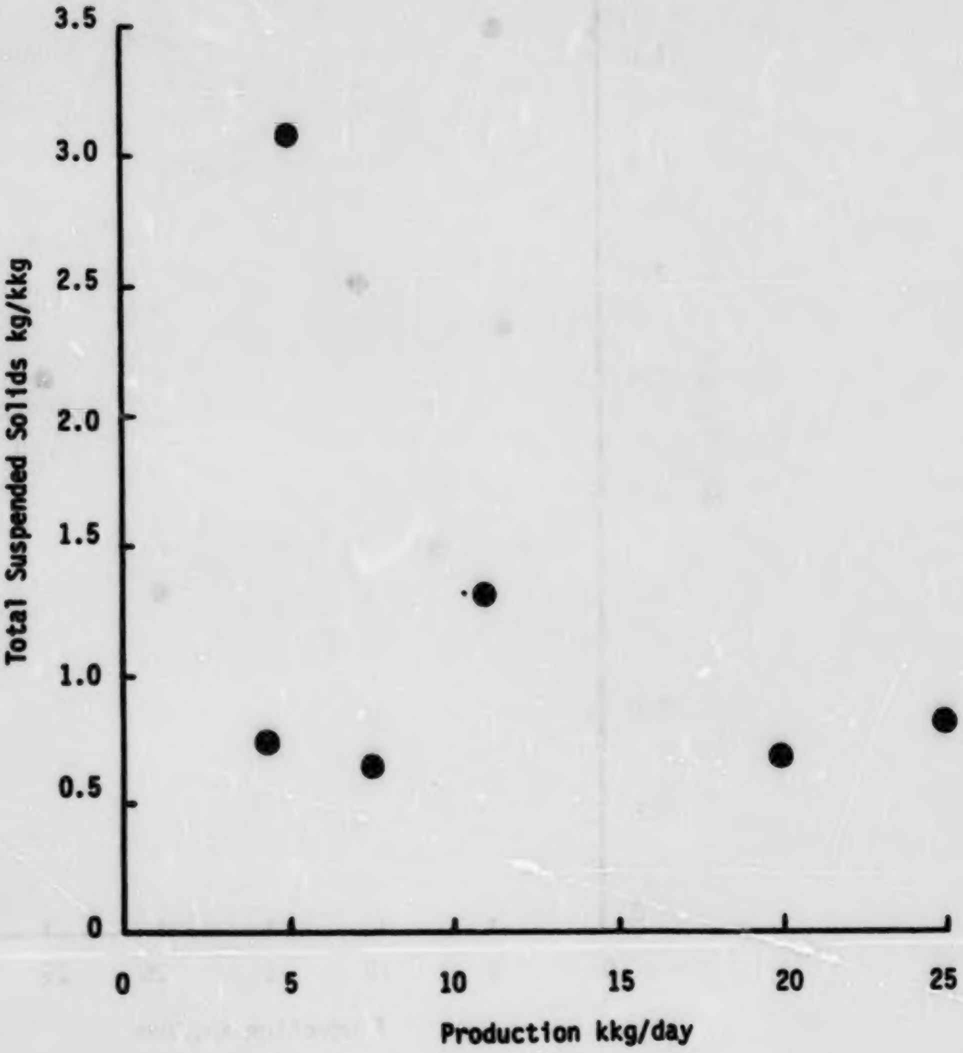


Figure 37
Hand-butchered salmon total suspended solids
versus production level

1. New England Groundfish--Figure 38 shows the flow diagram for a typical New England groundfish filleting process.

Fish arrive at the major processing centers, such as Gloucester, Boston, and New Bedford, by truck and boat. The resource has been declining in recent years; consequently, increasing numbers of fish are being trucked from northern New England and from Canada. Fish such as flounder and ocean perch arrive in the round, while larger species, such as cod and haddock, are often eviscerated at sea to minimize spoilage and maximize efficiency. The fish are typically unloaded from boats (by hand) into boxes, and then transported by forklift or dolly to the processing areas. Some ice accompanies the fish and a certain weight percentage is subtracted from the gross value to allow for this when the fish are weighed. The fish are stored on ice in the plant while awaiting processing.

Included in the plans to build a new fish pier in Boston is a vacuum system to transport fish from the boat holds into palletted bins. This will increase the unloading rate, while at the same time decreasing the amount of contaminated ice.

The fish are filleted by hand. Plants employ from 3 to 25 fillet cutters. The fish will be descaled prior to filleting if requested by the customer. Descaling is usually accomplished by hand; however, some descaling machines employ highpressure water jets. The flow from these mechanical descalers is relatively large and contains heavy waste loadings. Some plants use a continuous brine flow to keep the fish moist and firm on the filleting table, while other plants use an intermittent water flow to clean the tables between species. The fillets may be skinned manually (for special orders) except for various species of flounder, which are passed through a skinning machine. The skinning machine commonly used in New England is the German-made Baader 47 skinner.

The prepared fillets are placed in a preserving dip tank containing chilled brine with 10 percent sodium benzoate solution. The fish are removed from the dip tank by hand or by inclined conveyor, manually packed into boxes, and stored in a cooler. The great majority of groundfish are filleted and sold fresh. Some of the larger species, which are sold to markets, are handled whole, while those which are to be shipped longer distances are frozen.

Plant washdowns typically occur only once per day, in the last 20 minutes to one-half hour of operation. Both chlorinated salt water and fresh water are used. The solid material is typically shoveled into bins and trucked to a nearby rendering plant. During the peak lobster fishing period, carcases are often sold for lobster bait.

A frozen-whole process used in New England for whiting is shown in Figure 39. The whiting are taken from the boats in bushels

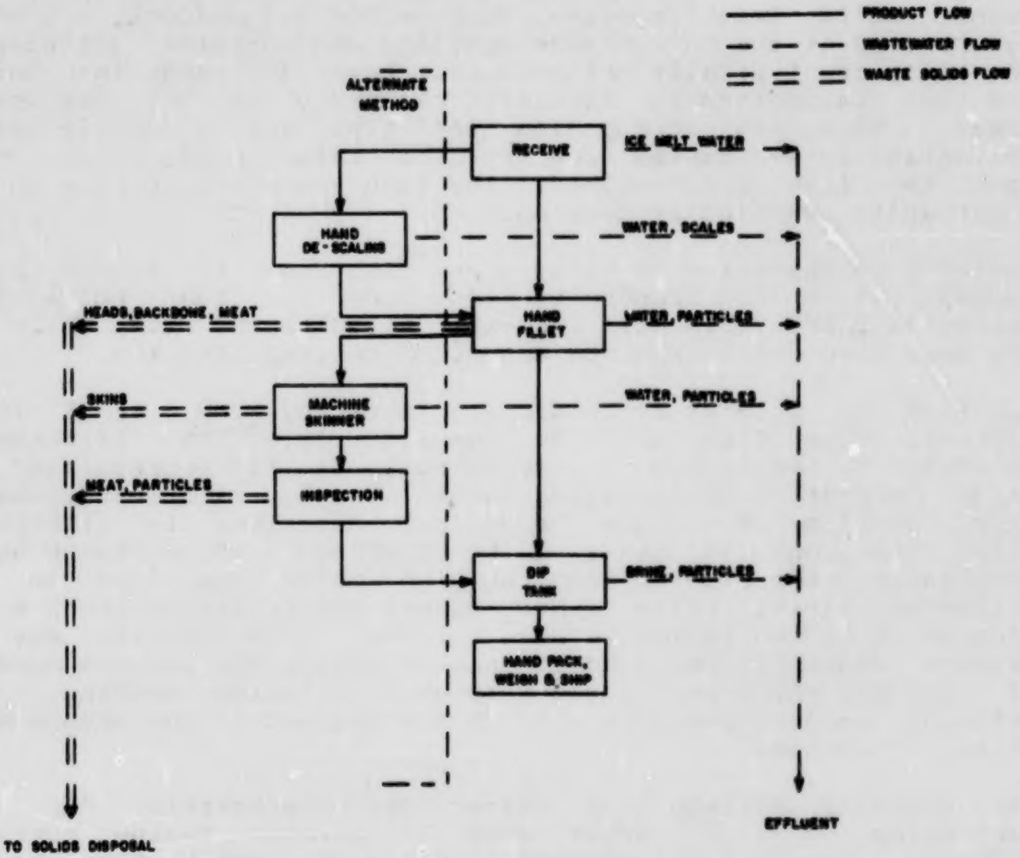

PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
ALTERNATE METHOD
RECEIVE
ICE MELT WATER
HAND DE-SCALING
WATER, SCALES
HEADS, BACKBONE, MEAT
HAND FILLET
WATER, PARTICLES
SKINS
MACHINE SKINNER
WATER, PARTICLES
MEAT, PARTICLES
INSPECTION
DIP TANK
BRINE, PARTICLES
HAND PACK, WEIGH & SHIP
EFFLUENT
TO SOLIDS DISPOSAL

Figure 38 . Typical New England ground fish process.

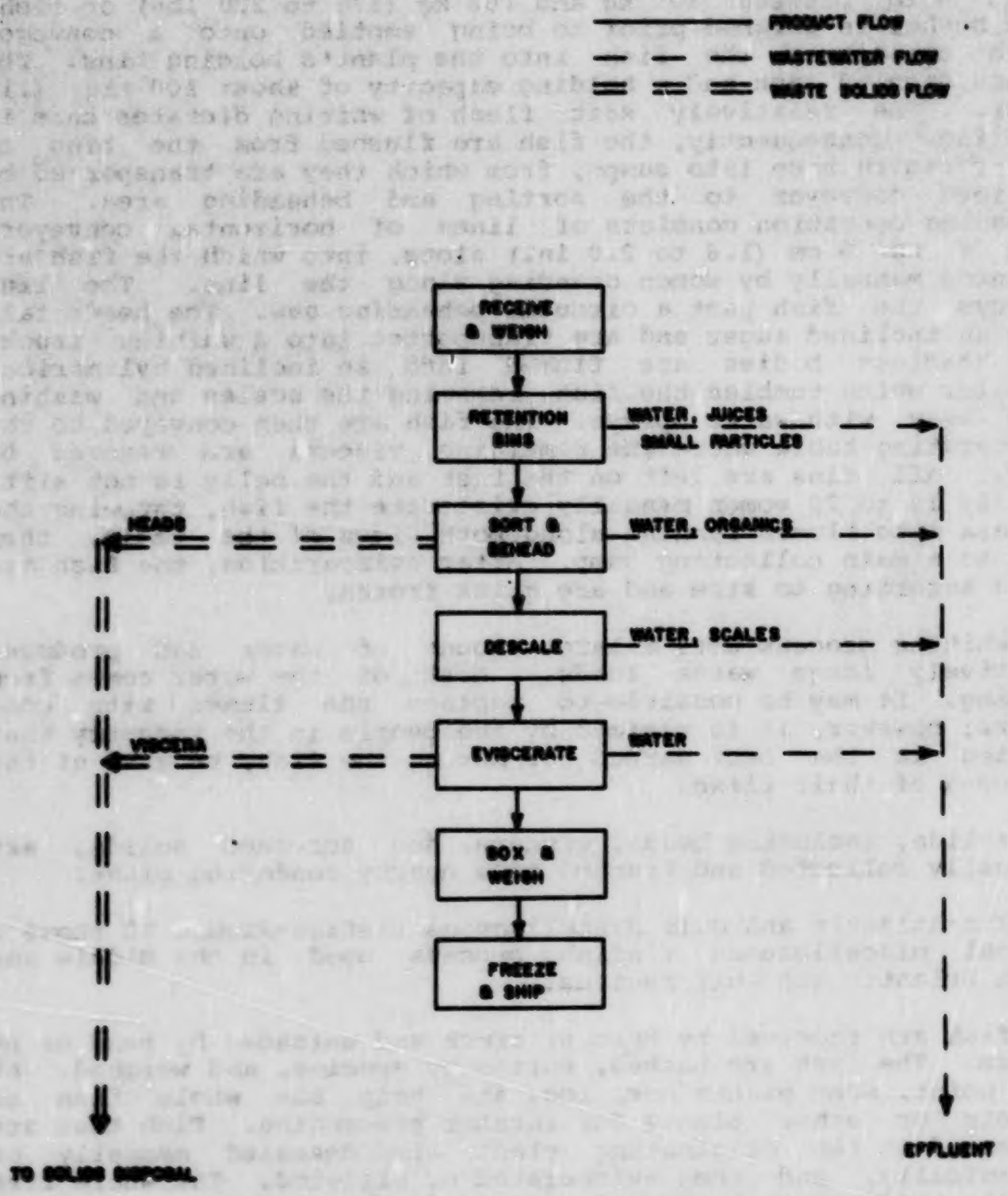

PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
RECEIVE & WEIGH
RETENTION BINS
WATER, JUICES SMALL PARTICLES
HEADS
SORT & BEHEAD
WATER, ORGANICS
DESCALE
WATER, SCALES
VISCERA
EVISCERATE
WATER
BOX & WEIGH
FREEZE & SHIP
TO SOLIDS DISPOSAL
EFFLUENT

**Figure 39 . Typical New England whiting process.**

which hold between 80 kg and 100 kg (176 to 220 lbs) of fish. Each bushel is weighed prior to being emptied onto a conveyor which transports the fish into the plant's holding bins. The plants sampled each had a holding capacity of about 100 kkg (110 tons). The relatively soft flesh of whiting dictates care in handling. Consequently, the fish are flushed from the bins by high-pressure hose into sumps, from which they are transported by inclined conveyor to the sorting and beheading area. The beheading operation consists of lines of horizontal conveyors with 4 to 5 cm (1.8 to 2.0 in.) slots, into which the fish are oriented manually by women standing along the line. The line conveys the fish past a circular beheading saw. The heads fall onto an inclined auger and are transported into a waiting truck. The headless bodies are flumed into an inclined cylindrical descaler which tumbles the fish, removing the scales and washing them away with water sprays. The fish are then conveyed to the eviscerating table where the remaining viscera are removed by hand. All fins are left on the fish and the belly is not slit. Usually 15 to 20 women manually eviscerate the fish, throwing the viscera into flumes running along both sides of the table, then out to a main collecting sump. After evisceration, the fish are boxed according to size and are quick frozen.

The whiting process uses a large amount of water and produces relatively large waste loads. Most of the water comes from fluming. It may be possible to replace the flumes with conveyors; however, it is claimed by the people in the industry that fluming is the best method for moving the fish, because of the softness of their flesh.

The solids, including heads, viscera, and screened solids, are typically collected and trucked to a nearby rendering plant.

2. Mid-Atlantic and Gulf Miscellaneous Finfish-Figure 40 shows a typical miscellaneous finfish process used in the Middle and South Atlantic and Gulf regions.

The fish are received by boat or truck and unloaded by hand or by vacuum. The fish are washed, sorted by species, and weighed. At this point, some plants box, ice, and ship the whole fish to markets or other plants for further processing. Fish that are processed at the originating plant are descaled manually or mechanically, and then eviscerated or filleted. The whole fish fillets are next packaged and shipped fresh or frozen. It was observed that more fish were handled in the round or eviscerated and frozen in these two regions than in New England. The solid fish wastes, including heads, viscera, and carcasses, are usually recovered for pet or mink food.

A relatively new process developing in the Gulf region is the utilization of flesh separating machinery. The process holds much promise because it can improve yields, utilize previously-ignored fish species, and satisfy ready markets. These factors tend to reduce operating costs and make the process economically

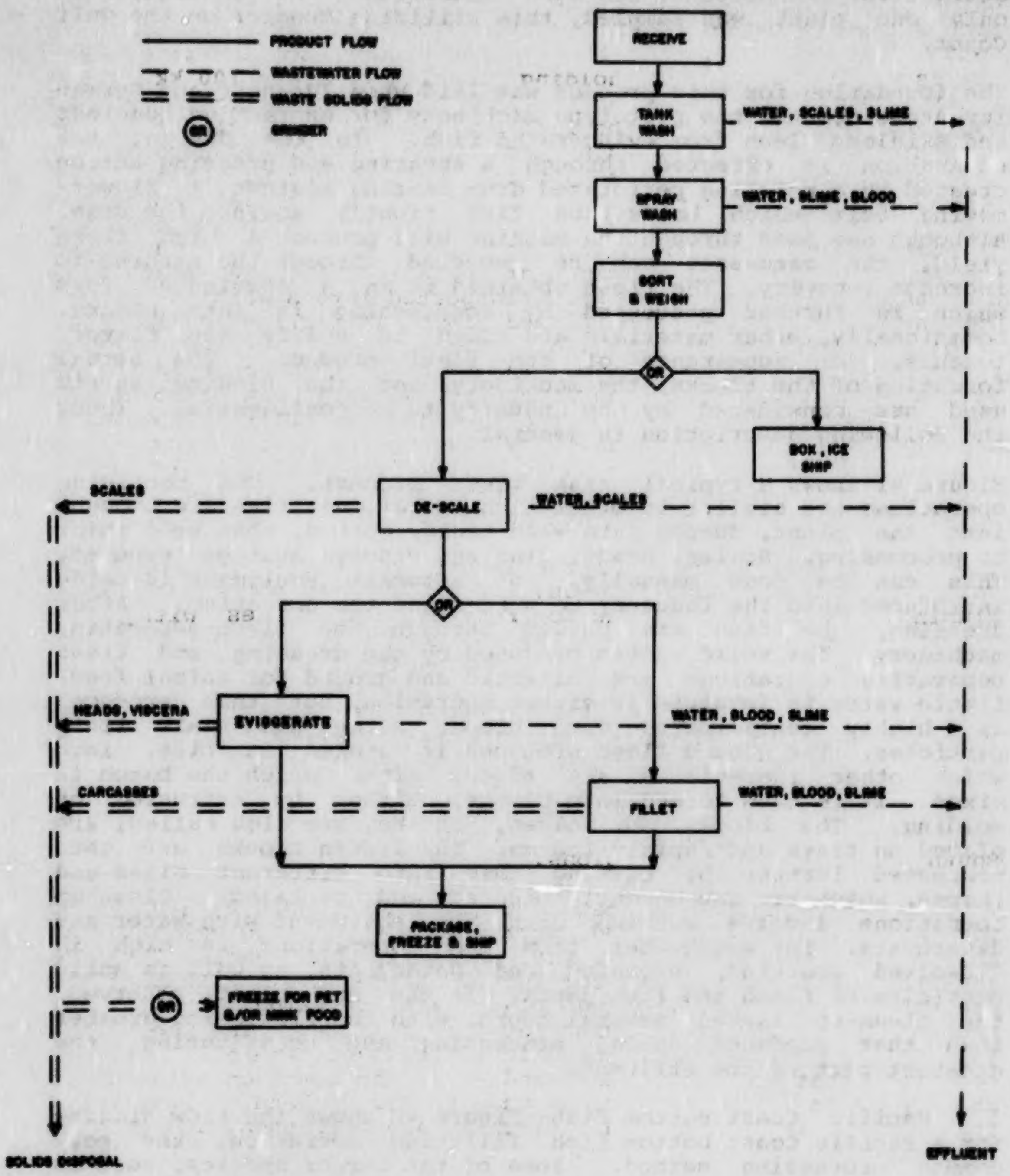

PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
GR
GRINDER
RECEIVE
TANK WASH
WATER, SCALES, SLIME
SPRAY WASH
WATER, SLIME, BLOOD
SORT & WEIGH
OR
BOX, ICE SHIP
SCALES
DE-SCALE
WATER, SCALES
OR
HEADS, VISCERA
EVISCERATE
WATER, BLOOD, SLIME
CARCASSES
FILLET
WATER, BLOOD, SLIME
PACKAGE, FREEZE & SHIP
GR
FREEZE FOR PET &/OR MINK FOOD
SOLIDS DISPOSAL
EFFLUENT

**Figure 40. Typical Mid-Atlantic or Gulf finfish process.**

attractive. At present, few such operations are on-line, and only one plant was sampled, this utilizing croaker on the Gulf Coast.

The foundation for this process was laid when Japanese and German inventors created the prototype machinery for extracting boneless and skinless flesh from eviscerated fish. In one design, the separation is effected through a shearing and pressing action created by a rotating perforated drum bearing against a slower-moving belt which holds the fish tightly against the drum. Although one pass through the machine will produce a high flesh yield, the carcasses can be recycled through the machine to increase recovery. The flesh obtained is in a comminuted form which is further processed by compressing it into blocks. Occasionally, other materials are added to modify the flavor, texture, or appearance of the final product. The actual formation of the blocks, the machinery, and the binding agents used are considered by the industry to be confidential. Thus, the following description is general.

Figure 41 shows a typical fish flesh process. The receiving operations are similar to other fish operations; fish are brought into the plant, dumped into wash tanks, sorted, then held prior to processing. Scales, heads, fins and viscera must be removed. This can be done manually, but automatic equipment is being introduced into the industry to streamline the operation. After dressing, the fish are passed through the flesh-separating machinery. The solid wastes produced by the dressing and flesh separating operations are collected and ground for animal feed. Little water is involved in either operation, but that produced is highly contaminated with blood, slime and small flesh particles. The ground flesh produced is stored in bins, into which other ingredients are added, after which the batch is mixed. It is then formed into blocks, either by extrusion or molding. The blocks, or cakes, as they are also called, are placed on trays and rapidly frozen. The frozen blocks are then processed further by cutting them into different sizes and shapes, which are subsequently breaded and packaged. Clean-up operations involve washing down the equipment with water and detergents. The wastewater from such operations is high in dissolved proteins, organics and detergents, as well as solid particles of flesh and fish parts. In the one plant observed, the clean-up lasted several hours, with the flow being greater than that produced during processing and constituting the greatest part of the effluent.

3. Pacific Coast Bottom Fish--Figure 42 shows the flow diagram for a Pacific Coast bottom fish filleting operation, the most common processing method. Some of the larger species, such as the black cod, are processed whole; and a small demand in fish markets exists for other whole fish.

The fish usually arrive by boat and are unloaded by hand. A few plants are converting to the vacuum unloading system. The fish

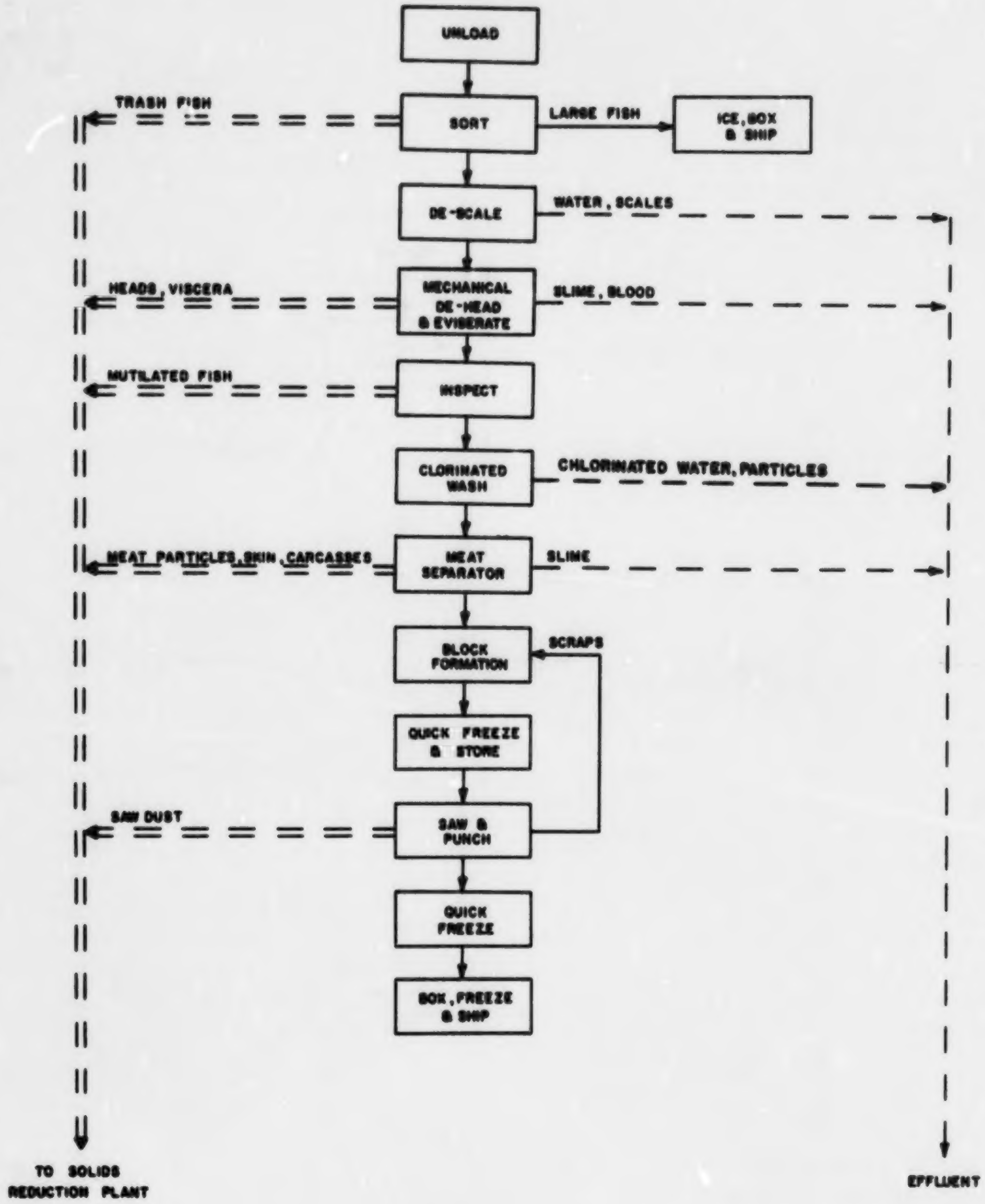

UNLOAD
SORT
TRASH FISH
LARGE FISH
ICE, BOX & SHIP
DE-SCALE
WATER, SCALES
MECHANICAL DE-HEAD & EVISERATE
HEADS, VISCERA
SLIME, BLOOD
INSPECT
MUTILATED FISH
CLORINATED WASH
CHLORINATED WATER, PARTICLES
MEAT SEPARATOR
MEAT PARTICLES, SKIN, CARCASSES
SLIME
BLOCK FORMATION
SCRAPS
QUICK FREEZE & STORE
SAW & PUNCH
SAW DUST
QUICK FREEZE
BOX, FREEZE & SHIP
TO SOLIDS REDUCTION PLANT
EFFLUENT

Figure 41 . Typical fish flesh process.

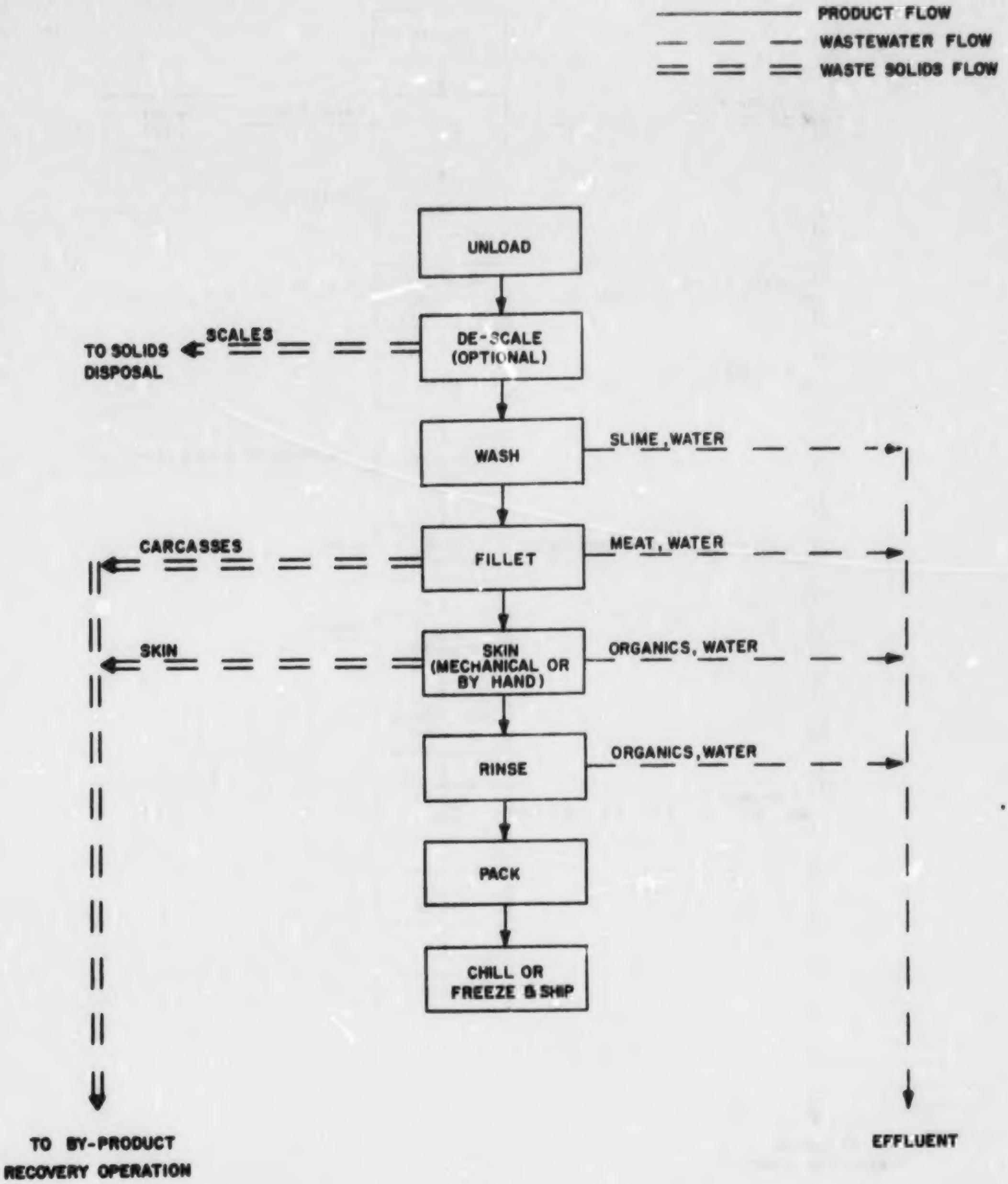

PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
UNLOAD
DE-SCALE (OPTIONAL)
SCALES
TO SOLIDS DISPOSAL
WASH
SLIME, WATER
FILLET
CARCASSES
MEAT, WATER
SKIN (MECHANICAL OR BY HAND)
SKIN
ORGANICS, WATER
RINSE
ORGANICS, WATER
PACK
CHILL OR FREEZE & SHIP
TO BY-PRODUCT RECOVERY OPERATION
EFFLUENT

**Figure 42 .** Typical Pacific Coast bottom fish process.

are weighed and sent to the filleting tables; the larger plants use a conveyor system for fish transport from the receiving room to the filleting room. Some plants use manual or mechanical descaling before filleting, depending on the ultimate product form. The fish are spray-washed on the conveyor or washed by hand as they are filleted. Water is available from a hose at each filleting position and in many plants is flowing constantly. Most plants use mechanical skinners after filleting; however, some skinning is done by hand and a few products require no skinning at all. The fish are rinsed in a tank containing preservatives and then packed for the fresh or frozen market.

Most of the solid waste from the Pacific Coast plants is ground and bagged for the pet or animal food market.

Some halibut are processed on the Northwest Pacific Coast in centers such as Bellingham and Seattle. The methods of processing are the same as described in the following discussion on laska bottom fish.

4. Alaska Bottom Fish--The only species of Alaskan bottom fish processed in any quantity at this time is halibut. Figure 43 shows the flow diagram for a typical halibut processing operation.

Since the average length of a trip in Alaska ranges from 13 to 25 days, the halibut are butchered at sea and iced. After receipt at the docks, the fish are beheaded, if this has not already been done at sea, and the body cavity is flushed to remove ice. The fish are graded by size and then processed whole or fletched. Smaller fish, under about 27 kg (60 lbs) are usually frozen, while those greater in size are butchered to remove four large sections of flesh called fletches. Some plants in Alaska freeze all sizes of fish, which are processed later in the Northwest.

The fish to be frozen whole are washed by spray or by hand and quick-frozen. The waste loadings from this operation are minimal. The sections of flesh from the fletched fish are trimmed, washed, and quick-frozen. The larger trimmings are marketed for smoking and breading. The edible cheeks are removed from the heads, and are trimmed, washed, bagged and frozen.

The solid wastes in Alaska are used for bait or are discarded.

## Subcategorization Rationale

Although there are many species and processing operations in the bottom/miscellaneous finfish subcategory, only two factors were considered to require further subcategorization: geographic location and degree of mechanization/water use. The bottom fish, groundfish, and miscellaneous finfish industry was subcategorized into "Alaska" and "non-Alaska" regions because of the greater costs and more complex treatment problems encountered in Alaska.

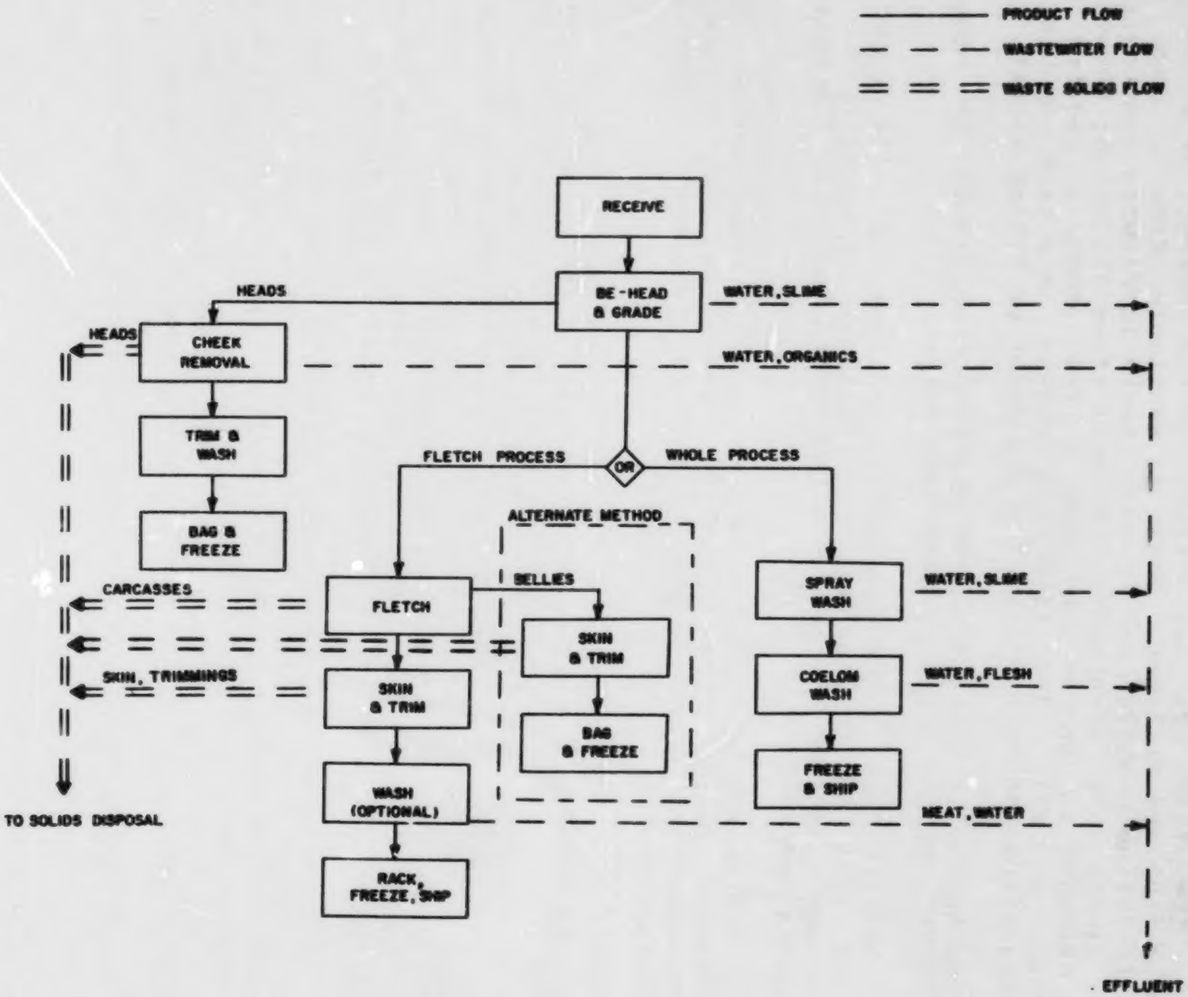

PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
RECEIVE
BE-HEAD & GRADE
HEADS
WATER, SLIME
HEADS
CHEEK REMOVAL
WATER, ORGANICS
TRIM & WASH
BAG & FREEZE
FLETCH PROCESS
OR
WHOLE PROCESS
ALTERNATE METHOD
BELLIES
CARCASSES
FLETCH
SKIN & TRIM
SKIN, TRIMMINGS
SKIN & TRIM
BAG & FREEZE
SPRAY WASH
WATER, SLIME
COELOM WASH
WATER, FLESH
FREEZE & SHIP
WASH (OPTIONAL)
MEAT, WATER
TO SOLIDS DISPOSAL
RACK, FREEZE, SHIP
EFFLUENT

Figure 43 . Typical Alaska or Northwest halibut process.

In Alaska, the only bottom fish industry of importance is halibut. The problem is complicated by the fact that the processing of halibut usually is practiced in conjunction with other processes, such as fresh/frozen salmon processing.

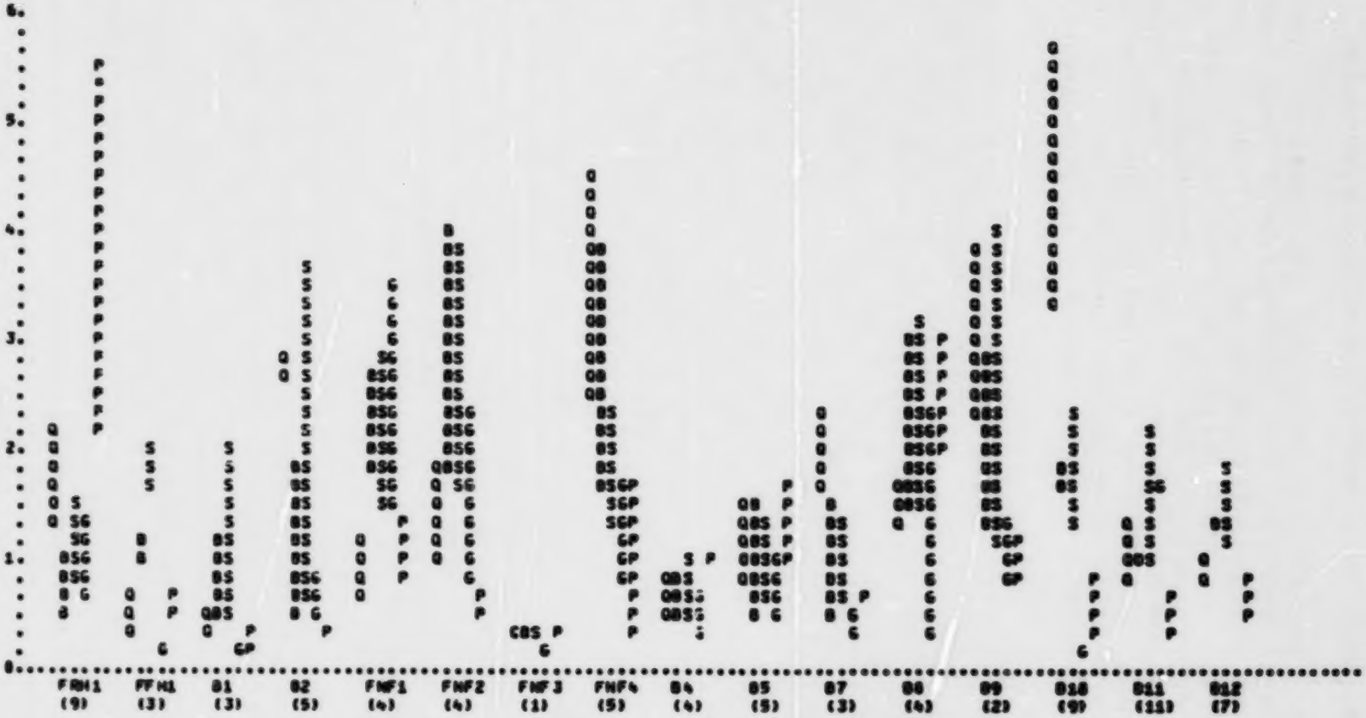
With respect to non-Alaska regions, the bottom fish/finfish industry was subcategorized into "conventional" and "mechanized" processes, due to the increased water and waste loads associated with the latter. A conventional process is defined as one in which the unit operations are carried out essentially by hand and with a relatively low water volume. However, the conventional process generally utilizes scaling and/or skinning machines. A mechanized process is defined as one in which many of the unit operations are mechanized and relatively large volumes of water are used.

Figure 44 summarizes the wastewater characteristics for what are considered to be conventional processing operations with little or no mechanization. Figure 45 depicts a summary plot for what are considered to be high-water-use mechanized processing operations. In Figure 44 codes FRH1 and FFH1 refer to halibut processing operations in Alaska; codes B1 and 2 refer to groundfish plants in New England; codes FNF1, 2, 3, and 4, to finfish plants in the Middle Atlantic and Gulf regions; codes B4, 5, 10, 11, and 12 refer to bottom fish plants in the Northwest; and codes B7, 8, and 9 refer to bottom fish plants in California. With respect to Figure 45, codes W1 and 2 refer to whiting plants in New England, CFC1 to a fish flesh plant in the Gulf, and B6 and B6H to a bottom fish plant in the Northwest. Code B6H represents historical data obtained for plant B6 (21).

The plants represented by codes FRH1 and FFH1 are considered to be large halibut processing operations. The waste loads from the halibut processing operations are relatively low, being of the same order of magnitude as the Alaska fresh/frozen salmon process. Table 26 shows summary statistics of the waste loads from the Alaska halibut process. It is assumed that the waste per unit of production is the same for plants in either the large or small categories.

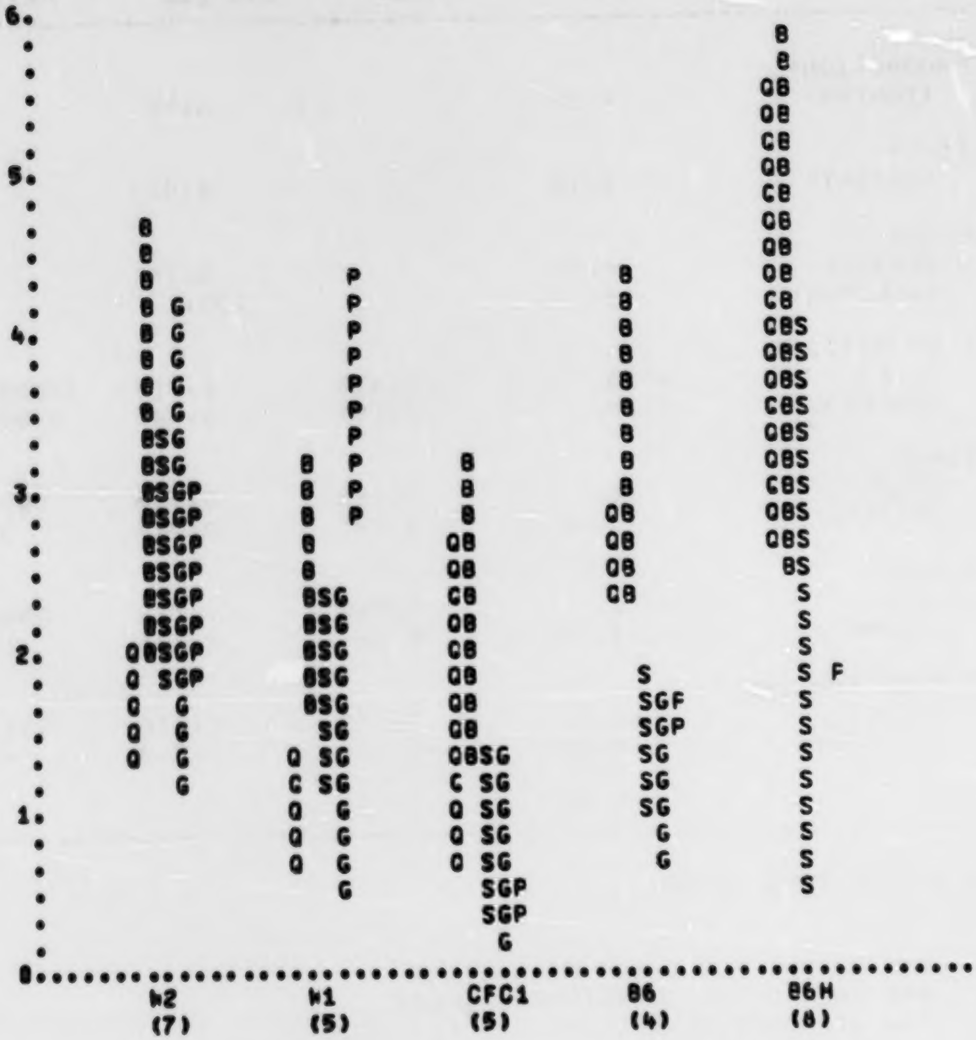
A relatively large size range exists for both the non-Alaska conventional and non-Alaska mechanized portions of the industry, with the mechanized portion being larger, on the average. Information on the annual production of bottom fish is limited. Based on studies conducted in the Northwest (20), and observations made during this study, the following divisions were made to break the industry into approximately equal-size ranges for the purpose of costing control and treatment technologies. The division between "large" and "medium" conventional plants was set at 3630 kkg (4000 tons) of raw product processed annually and the division between "medium" and "small" conventional plants was set at 1810 kkg (2000 tons) of raw product processed annually. The division between "large" and "small" mechanized plants was set at 3630 kkg (4000 tons) of raw product processed annually.

Figure 44 . CONVENTIONAL BOTTOM FISH PROCESS PLOT.



| SYMBOL | PARAMETER | SCALING FACTOR |
|---|---|---|
| Q | FLOW | 1 INCH = 5000 L/KKG |
| B | 5 DAY BOD | 1 INCH = 2 KG/KKG |
| S | SUSPENDED SOLIDS | 1 INCH = 1 KG/KKG |
| G | GREASE AND OIL | 1 INCH = 0.5 KG/KKG |
| P | PRODUCTION | 1 INCH = 2 TON/HR |

**Figure 45. MECHANIZED BOTTOM FISH PROCESS PLOT.**



| SYMBOL | PARAMETER | SCALING FACTOR |
|---|---|---|
| Q | FLOW | 1 INCH = 10000 L/KKG |
| B | 5 DAY BOD | 1 INCH = 5 KG/KKG |
| S | SUSPENDED SOLIDS | 1 INCH = 5 KG/KKG |
| G | GREASE & OIL | 1 INCH = 2 KG/KKG |
| P | PRODUCTION | 1 INCH = 2 TON/HR |

Table 26

## ALASKAN BOTTOM FISH
## PROCESS SUMMARY OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION* | | | | |
| (TON/HR) | 4.38 | | 4.60 | |
| TIME* | | | | |
| (HR/DAY) | 5.13 | | 0.523 | |
| FLOW* | | | | |
| (L/SEC) | 6.94 | | 8.74 | |
| (GAL/MIN) | 110. | | 139. | |
| FLOW RATIO** | | | | |
| (L/KKG) | 4530. | 8.418 | 0.907 | 37500. |
| (GAL/TON) | 1080. | 6.989 | 0.907 | 8980. |
| TSS** | | | | |
| (MG/L) | 326. | 5.788 | 0.318 | 685. |
| (KG/KKG) | 1.48 | 0.390 | 0.318 | 3.10 |
| BOD-5** | | | | |
| (MG/L) | 396. | 5.982 | 0.216 | 686. |
| (KG/KKG) | 1.79 | 0.584 | 0.216 | 2.97 |
| GREASE AND OIL** | | | | |
| (MG/L) | 44.6 | 3.798 | 1.310 | 944. |
| (KG/KKG) | 0.202 | -1.600 | 1.310 | 4.27 |
| PH* | 6.73 | | | |

PLANTS FRM1 ,FFM1

* THE OUTPUT FOR THESE PARAMETERS
ARE THE NORMAL (UNWEIGHTED) MEAN
AND STANDARD DEVIATION, RESPECTIVELY

** THE OUTPUT FOR THESE PARAMETERS
ARE THE LOG NORMAL (UNWEIGHTED) MEAN
AND STANDARD DEVIATION, RESPECTIVELY

Table 27 indicates distribution within the selected size ranges, of the plants investigated.

Although some variability was evident between the plants in the "conventional" and "mechanized" subcategories, especially the flow ratio and production parameters, the following observations were noted. The waste loads (in terms of BOD, suspended solids, and grease and oil) were four to five times greater for the mechanized operations than the conventional operations. The highly variable flow ratios for the conventional operations were attributed mainly to the different methods of washing the fish before processing. For example, the high flow ratio exhibited by plant B10 was partially due to the fact that a high-velocity jet spray was used to wash the fish as they were conveyed to the processing lines. The historical flow ratio data at plant B9 were obtained from a flow meter which also serviced a restaurant. The flow to the filleting tables at plant B2 was excessive in relation to the same unit operation at other plants. Plant FNF4 flow ratio data were relatively high in comparison to other bottom fish plants even though the other waste parameters were low.

Since the waste loads were relatively low and were uniform for all the conventional bottom/miscellaneous finfish processes, it was reasonable to place them into one subcategory. Table 28 summarizes the waste parameters for the non-Alaska conventional bottom/miscellaneous finfish plants. The flow ratios were not included for B2, B9, B10, and FNF4, as they were not considered to be typical. Plant FNF3 was not included in the average because only a small number of fish were being handled in the round on the day the sample was taken, a situation which was considered to be atypical.

Because there is no apparent relationship or trend relating flow ratios, TSS ratios, or BOD5 ratios to production levels (See Figures 46, 47, and 48), it was assumed that the waste loads per unit of production are independent of production levels.

The plants used to represent the mechanized bottom/miscellaneous finfish process were two New England whiting plants (W1, W2), a fish flesh plant on the Gulf (CFC1), and a bottom fish plant in the Northwest (B6, B6H). Plant B6 was included in the mechanized subcategory because it used a mechanical scaler with high-velocity water jets. Since this was the only scaler of this type observed, and it contributed a high percentage of the waste load, it could not be considered typical. Plant CFC1 was also included in the mechanized subcategory, since mechanical beheading and eviscerating machinery was used. The waste loads for the two whiting plants and the fish flesh plant were considered to be the most representative of the mechanized segment of the industry and are summarized in Table 29.

## SARDINE CANNING

**Table 27 Non-Alaska bottom fish size distribution.**

| | Type of Process | |
|---|---|---|
| Size | Conventional | Mechanized |
| Large | FNF4, B8 | W1, W2, B6 |
| Medium | B5, B7, B9,<br>FNF1, FNF2,<br>B10, B11, B12 | -- |
| Small | B1, B2, B4,<br>FNF3 | CFC1 |

## Table 28

### CONVENTIONAL BOTTOM FISH
### PROCESS SUMMARY
### OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION (TON/HR)* | 1.79 | | 1.33 | |
| TIME (HR/DAY)* | 6.98 | | 0.642 | |
| FLOW (L/SEC)* | 3.75 | | 3.00 | |
| (GAL/MIN)* | 59.6 | | 47.6 | |
| FLOW RATIO (L/KKG) | 5240 | 8.56 | 0.058 | 5990 |
| (GAL/TON) | 1270 | 7.15 | 0.052 | 1440 |
| TSS (MG/L) | 271 | 5.60 | 0.163 | 396 |
| (KG/KKG) | 1.42 | 0.353 | 0.163 | 2.00 |
| BOD-5 (MG/L) | 633 | 6.45 | 0.152 | 901 |
| (KG/KKG) | 3.32 | 1.20 | 0.152 | 4.72 |
| GREASE AND OIL (MG/L) | 66.4 | 4.20 | 0.199 | 105 |
| (KG/KKG) | 0.348 | -1.06 | 0.199 | 0.553 |
| PH* | 6.79 | | 0.961 | |

PLANTS B1 ,B2 ,B4 ,B5 ,B7 ,B8 ,B9 ,B10 ,
B11 ,B12 ,FNF1,FNF2,FNF4

* NOTE: THE OUTPUTS FOR THESE PARAMETERS
ARE THE NORMAL (UNWEIGHTED) MEAN
AND STANDARD DEVIATION, RESPECTIVELY

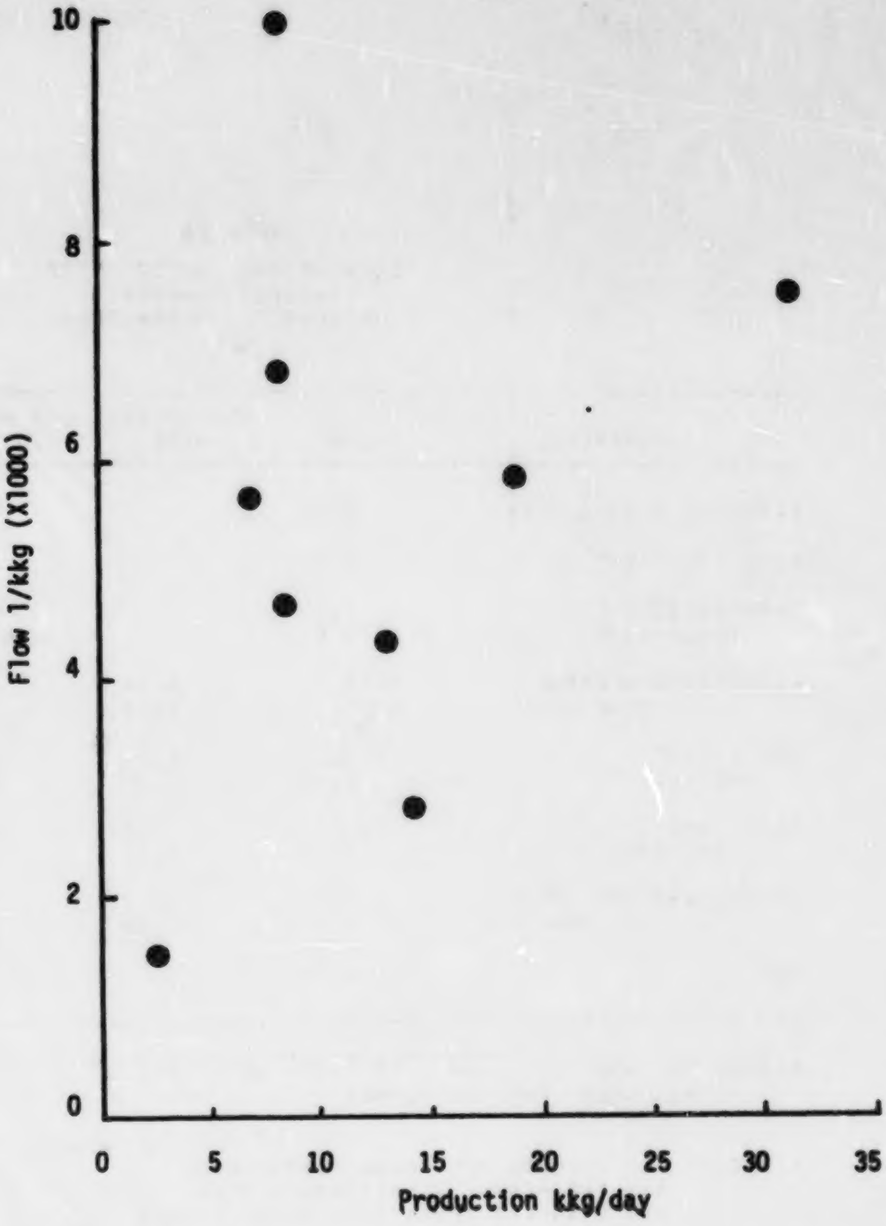


Figure 46
Conventional bottom fish flow ratios
versus production levels

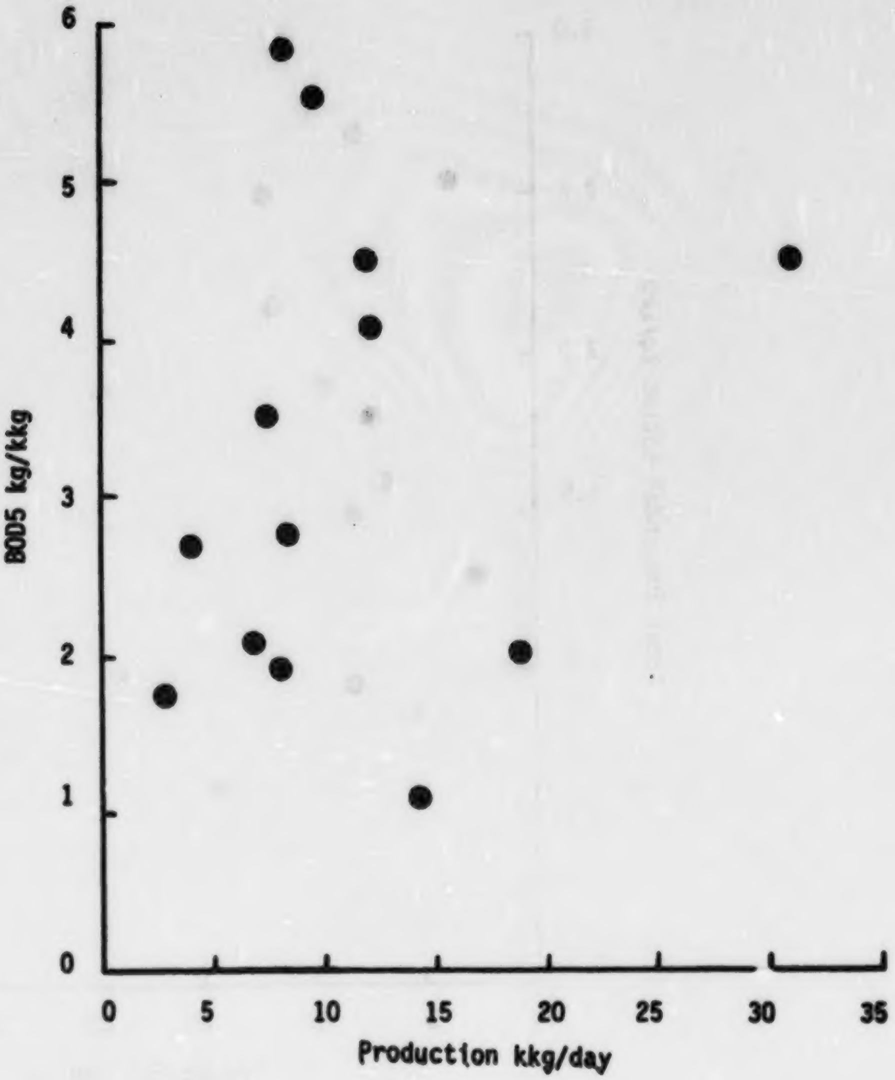


Figure 47
Conventional bottom fish BOD5 ratios
versus production levels

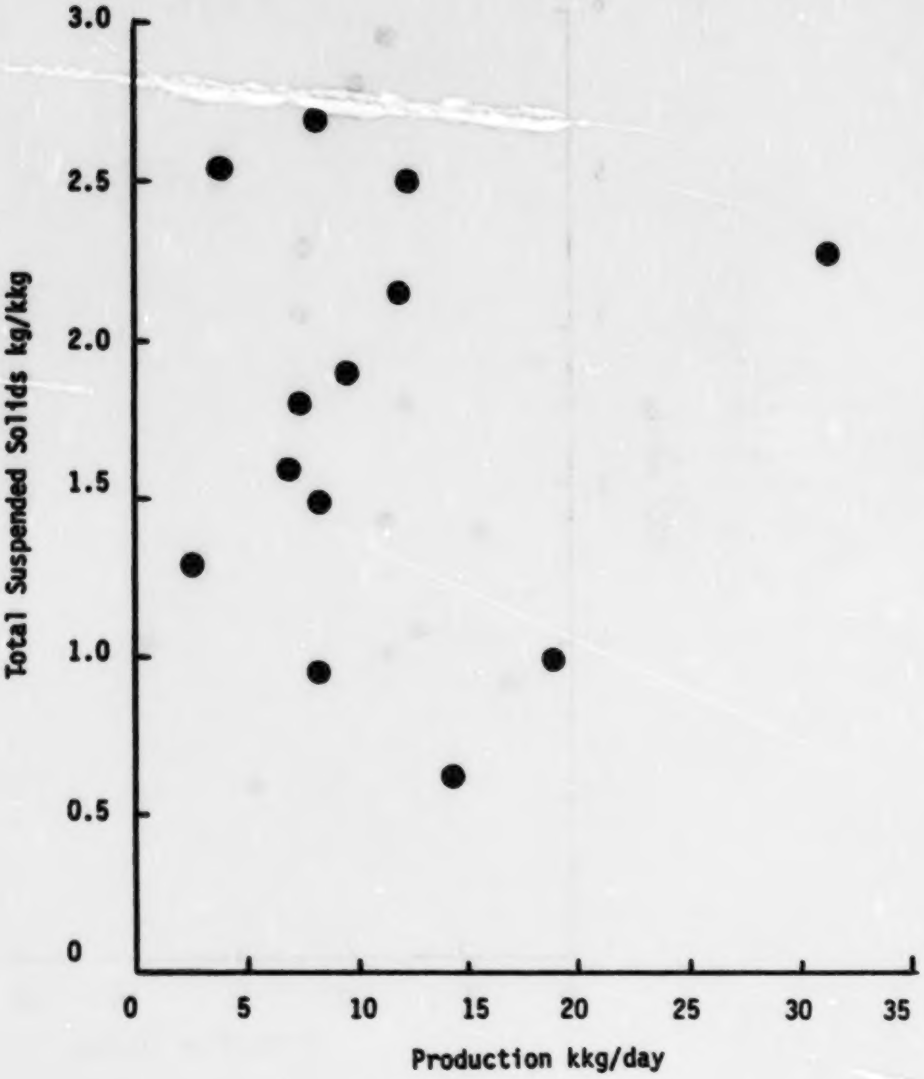


Figure 48
Conventional bottom fish total suspended solids ratios versus production levels

## Table 29

### MECHANICAL BOTTOM FISH
### PROCESS SUMMARY
### OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION (TON/HR)* | 4.21 | | 3.10 | |
| TIME (HR/DAY)* | 6.27 | | 2.86 | |
| FLOW (L/SEC)* | 13.3 | | 8.73 | |
| (GAL/MIN)* | 211 | | 139 | |
| FLOW RATIO (L/KKG) | 13500 | 9.51 | 0.211 | 22100 |
| (GAL/TON) | 3240 | 8.09 | 0.211 | 5290 |
| TSS (MG/L) | 659 | 6.49 | 0.183 | 1010 |
| (KG/KKG) | 8.92 | 2.19 | 0.183 | 13.7 |
| BOD-5 (MG/L) | 878 | 6.78 | 0.132 | 1190 |
| (KG/KKG) | 11.9 | 2.48 | 0.132 | 16.2 |
| GREASE AND OIL (MG/L) | 183 | 5.21 | 0.357 | 421 |
| (KG/KKG) | 2.48 | 0.909 | 0.357 | 5.70 |
| PH* | 7.29 | | 0.393 | |

PLANTS CFC1,W1 ,W2

* NOTE: THE OUTPUTS FOR THESE PARAMETERS
ARE THE NORMAL (UNWEIGHTED) MEAN
AND STANDARD DEVIATION, RESPECTIVELY

The canning of sea herring for sardines was considered to be an important segment of the seafood industry from a waste impact viewpoint due to its relatively large waste loads and flows and its seasonal or variable nature. Four sardine canning plants were visited in Maine; however, only two were sampled, as considerable historical data were available from a study conducted by the Maine Sardine Council (22). A total of 86 unit operation and effluent composite samples were collected (or otherwise made available) from the sardine industry.

## Process Description

Figure 49 shows the flow diagram for a typical Maine sardine canning plant. Although the process varies somewhat from plant to plant, it consists essentially of the following unit operations.

The fish arrive at the plant by boat or truck. Fish arriving by boat are pumped out of the holds and transported to storage bins by flume or dry conveyor. The water used is composed of transport brine from the hold and tidal water of varying salinity. This unloading water is usually discharged back to the local tidal waters. Fish arriving by truck are flumed or conveyed to storage tanks, or directly to the packing table.

Fish that are stored for significant lengths of time (one to two days) are preserved by the addition of concentrated brine solution to the storage bins. This is generally recycled through refrigeration units to maintain low temperatures within the tanks. The fish are removed from the storage bins by dip net, or are flushed out with large hoses. Fish are then either flumed or dry-conveyed to the cutting and packing tables.

The heads and tails are generally removed by hand; however, cutting machines for packing fish steaks are now being used on a limited basis. The size of head and tail portions removed depends on the fish size. The cutting and packing table is generally supplied continuously with fish, using a conveyor or flume. Fish remaining at the end of the conveyor are returned to the head of the line. All solid waste, consisting of heads, tails, and rejects from the packing line, are transported by water flume or dry conveyor to storage hoppers or directly to a waiting truck. These solids are usually hauled to reduction plants, where they are processed into fish meal or sold to lobstermen for bait.

After packing, open cans of sardines are placed in racks which are stacked onto special hand-trucks which are then rolled into a steam box for precooking. The fish are precooked for about 30 minutes at about 100°C (212°F), then removed from the steam box, drained and cooled to room temperature prior to sealing. This operation partially cooks the fish and removes undesirable oils.

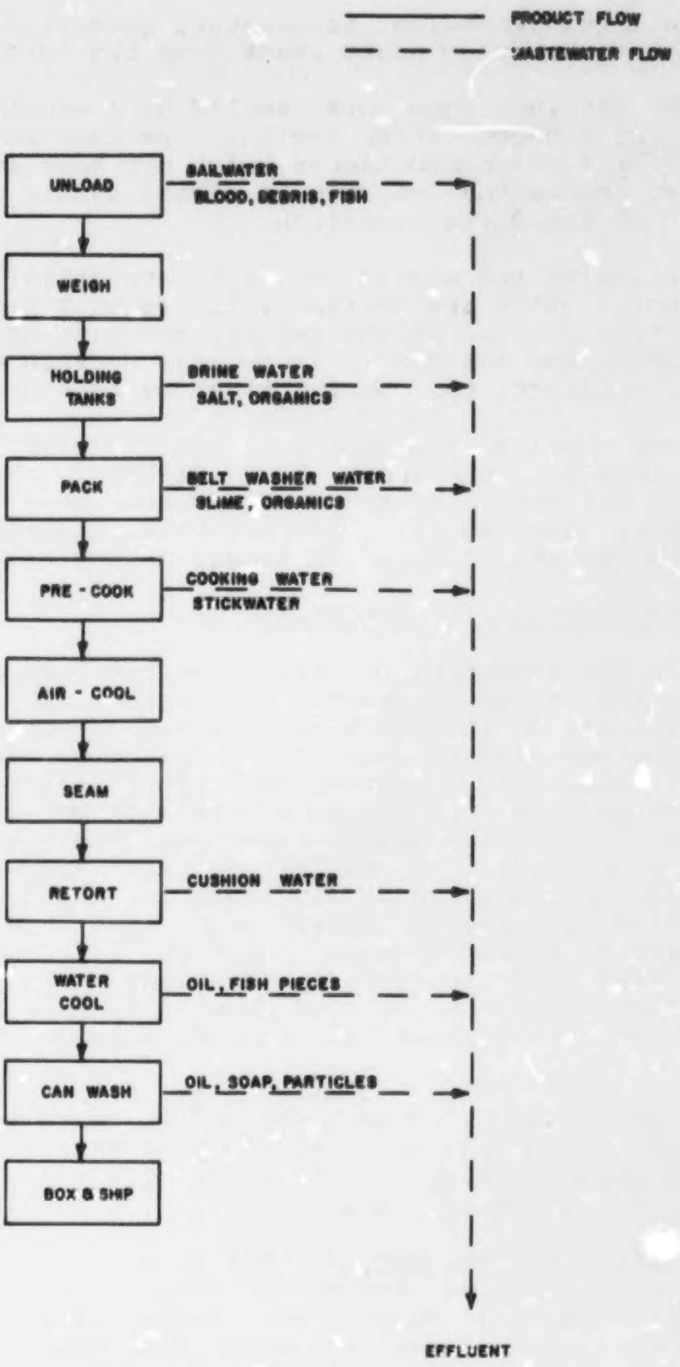

PRODUCT FLOW
WASTEWATER FLOW
UNLOAD
BAILWATER
BLOOD, DEBRIS, FISH
WEIGH
HOLDING TANKS
BRINE WATER
SALT, ORGANICS
PACK
BELT WASHER WATER
SLIME, ORGANICS
PRE - COOK
COOKING WATER
STICKWATER
AIR - COOL
SEAM
RETORT
CUSHION WATER
WATER COOL
OIL, FISH PIECES
CAN WASH
OIL, SOAP, PARTICLES
BOX & SHIP
EFFLUENT

Figure 49 . Typical sardine canning process.

The liquid waste, or stickwater, generated represents one of the most troublesome waste loads from the sardine operation.

The sardine cans are sealed by a machine which also adds oils and/or sauces. After sealing, the cans are washed to remove any oil or foreign substances which may have adhered to the can. The wash operation employs a closed system which is emptied at the end of the day's operation.

The sealed and washed cans are automatically loaded into vertical retorts which are partially filled with water to cushion the cans as they enter. In the retort, the cans are cooked at about 113°C (235°F) for one hour. If sauces, such as mustard or tomato sauce are utilized, the cooking time may be reduced to 50 minutes.

After cooking, the cans are water-cooled in the retort to a temperature of about 52°C (126°F). The cans are then removed from the bottom of the retort where they are washed again to remove any spots. They are then conveyed to holding bins where they are stored prior to manual casing.

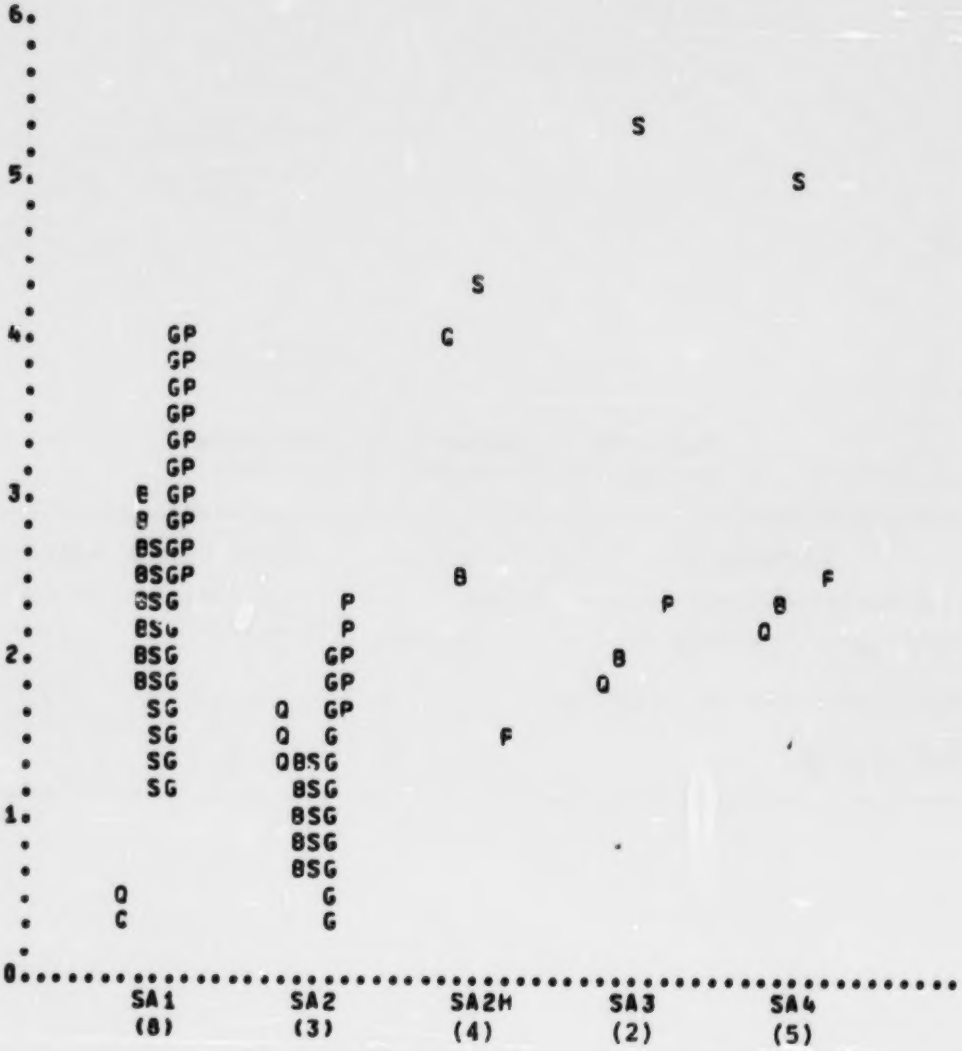
## Subcategorization Rationale

With the exception of dry versus wet transportation systems the sardine canning process is essentially the same from plant to plant and is located mainly in one geographical region, futher subcategorization was not considered necessary. However, the 1977 limitations provide for those plants with dry conveying systems and for those plants with wet flume conveying systems. The 1983 and new source standards are based on dry conveying systems only. A relatively low number of sardine plants are still operating; however, their sizes range widely. Of the 17 active processing operations, five were considered to be large (over 55 thousand cases annually) for the purpose of costing control and treatment technology, eight were considered to be medium (30 to 55 thousand cases annually) and four small (10). Ten of the 17 plants are located outside of population centers.

Figure 50 is a summary plot of the characteristics of four sardine plants. Plants SA1 and SA2 were investigated during this study. Information on plants SA2, SA3, and SA4 was obtained from the Maine Sardine Council study (22). All four plants were in the "large" size range.

Plants SA1, SA2, SA3, and SA4 used dry conveyors to move the fish from the holding bins to the packing lines. This should decrease the flow and reduce the waste load (because it reduces the contact time of the fish with the water). Table 30 compares flows and waste loads at plant SA2 before and after implementation of the belt conveyor. Table 31 lists summary waste characterization data obtained from the Main Sardine Council study (22) for in-plant fish fluming.

Figure 50 SARDINE CANNING PROCESS PLOT.



| SYMBOL | PARAMETER | SCALING FACTOR |
|---|---|---|
| Q | FLOW | 1 INCH = 5000 L/KKG |
| B | 5 DAY BOD | 1 INCH = 5 KG/KKG |
| S | SUSPENDED SOLIDS | 1 INCH = 2 KG/KKG |
| G | GREASE & OIL | 1 INCH = 1 KG/KKG |
| P | PRODUCTION | 1 INCH = 2 TON/HR |

Table 30 . Waste load reduction using dry conveyor (Plant SA2).

| Parameter | Before | After | % Reduction |
|---|---|---|---|
| Flow ratio (l/kkg) | 20,400 | 7590 | 63 |
| Suspended solids (kg/kkg) | 8.7 | 2.0 | 77 |
| BOD (kg/kkg) | 12.3 | 5.0 | 59 |

## TABLE 31
## SARDINE IN-PLANT FISH TRANSPORT WATER, STORAGE AREA TO PACKING AREA - (22)

| | | |
|---|---|---|
| Production | 24.5 | tons/day |
| | 22.2 | kkg/day |
| Fish Transport Water Use | 70,000 | gal/day |
| | 265,000 | l/kkg |
| Flow Ratio | 12,000 | l/kkg |
| | 2,860 | gal/ton |
| BOD5 | 1,400 | mg/l |
| | 16.7 | kg/kkg |
| TSS | 500 | mg/l |
| | 5.96 | kg/kkg |
| Oil & Grease | 120 | mg/l |
| | 1.43 | kg/kkg |

Table 32 summarizes waste loads statistics for the plants which utilize dry transportation systems. The flow ratio from plant SA1 was omitted from the summary data because the unique fish handling technology at the plant resulted in very low flows in comparison to the other plants studied. It was assumed that the waste load per unit of production is independent of production level.

## HERRING FILLETING

The sea herring fillet processing industry is typified by large flows and waste loadings; however, it was considered to be less important than the canning segment of the herring industry because very few filleting operations exist in the United States. The market outlook is promising; therefore, two plants, one in New England and one in Alaska, were investigated. In addition, historical data from a plant in the Maritime region of Canada were obtained, providing a total of 11 composite unit operation and end-of-pipe samples.

### Process Description

Figure 51 presents the flow diagram for a typical herring filleting process. In New England, the herring are received from boats or trucks and are pumped into the plant as a fish-water slurry. The scales are removed using a descaler on the boat in a manner similar to that used in the sardine industry.

The fish may be iced down before being flushed by high pressure hoses toward an inclined conveyor, which transports them into the processing room. German-made "Baader 33" filleting machines were used for processing the herring at the plant visited in New England.

In the Alaskan operation the herring were transported in bins and processed using "Arenco" filleting machines, made in Sweden.

In the filleting machines, the fish are oriented into groves and conveyed to a saw. The machines remove the heads, tails and viscera and finally fillet the herring in one operation.

The differences observed between the Arenco and the Baader filleting machines were:

1) The Arenco machine used two counter-rotating, grooved wheels which partially eviscerated the fish after beheading. This pair of wheels became less effective as viscera accumulated on them. This problem was reduced by directing a high-pressure water stream onto them during operation.

2) Instead of a single circular horizontal knife

## Table 32

## SARDINE
## PROCESS SUMMARY OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION* | | | | |
| (TON/HR) | 5.14 | | 0.946 | |
| TIME* | | | | |
| (HR/DAY) | 6.78 | | 1.42 | |
| FLOW* | | | | |
| (L/SEC) | 10.6 | | 3.25 | |
| (GAL/MIN) | 168. | | 51.5 | |
| FLOW RATIO** | | | | |
| (L/KKG) | 8690. | 9.069 | 0.275 | 16500. |
| (GAL/TON) | 2080. | 7.641 | 0.275 | 3950. |
| TSS** | | | | |
| (MG/L) | 623. | 6.435 | 0.811 | 4120. |
| (KG/KKG) | 5.41 | 1.689 | 0.811 | 35.8 |
| BOD-5** | | | | |
| (MG/L) | 1060. | 6.967 | 0.412 | 2770. |
| (KG/KKG) | 9.22 | 2.221 | 0.412 | 24.1 |
| GREASE AND OIL** | | | | |
| (MG/L) | 201. | 5.301 | 0.588 | 789. |
| (KG/KKG) | 1.74 | 0.555 | 0.588 | 6.85 |
| PH* | 6.36 | | | |

PLANTS SA1 ,SA2 ,SA3 ,SA4

* THE OUTPUT FOR THESE PARAMETERS ARE THE NORMAL (UNWEIGHTED) MEAN AND STANDARD DEVIATION, RESPECTIVELY

** THE OUTPUT FOR THESE PARAMETERS ARE THE LOG NORMAL (UNWEIGHTED) MEAN AND STANDARD DEVIATION, RESPECTIVELY

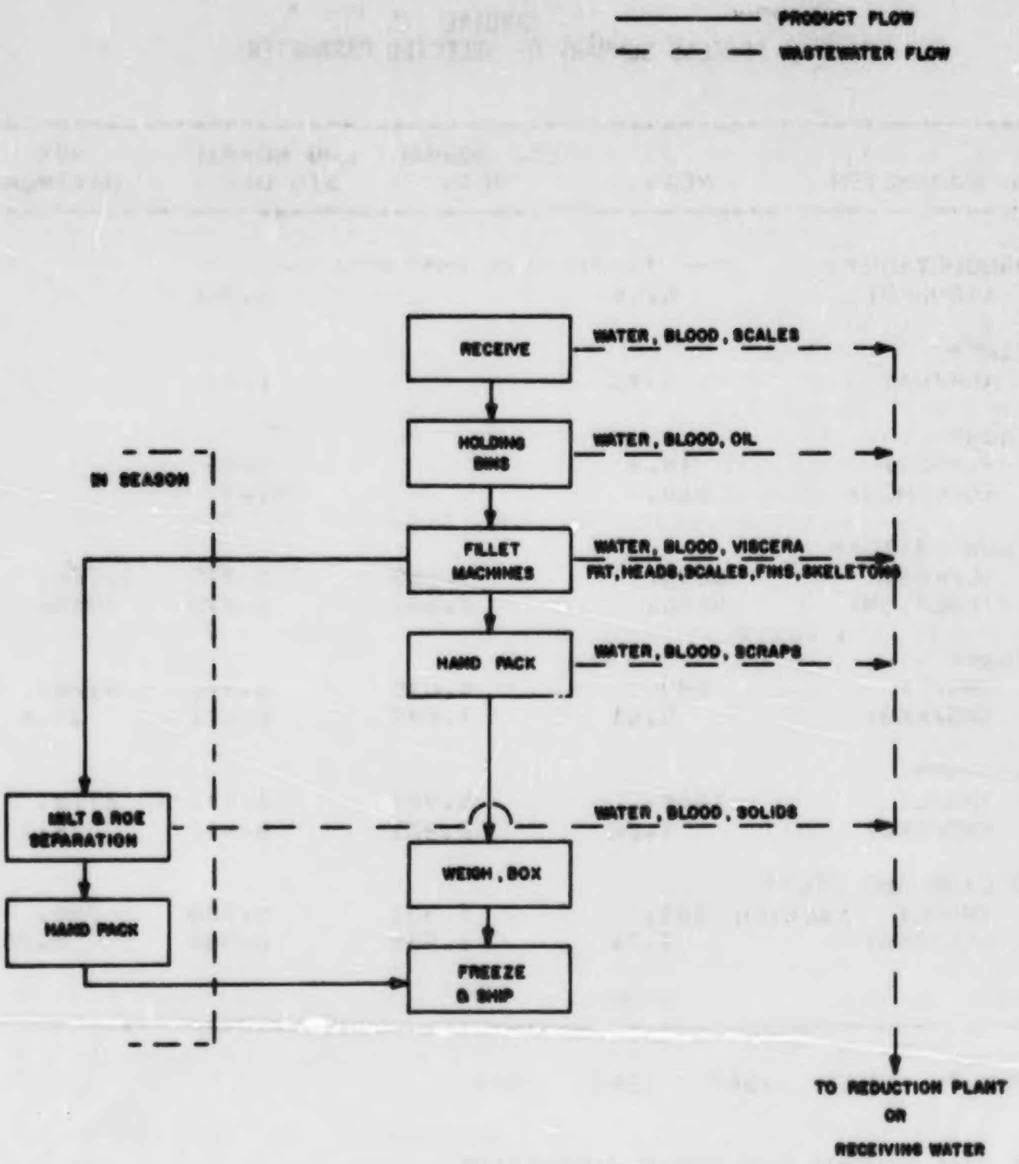

PRODUCT FLOW
WASTEWATER FLOW
RECEIVE
WATER, BLOOD, SCALES
HOLDING BINS
WATER, BLOOD, OIL
IN SEASON
FILLET MACHINES
WATER, BLOOD, VISCERA
FAT, HEADS, SCALES, FINS, SKELETONS
HAND PACK
WATER, BLOOD, SCRAPS
MILT & ROE SEPARATION
WATER, BLOOD, SOLIDS
WEIGH, BOX
HAND PACK
FREEZE & SHIP
TO REDUCTION PLANT
OR
RECEIVING WATER

Figure 51. Typical herring filleting process.

for slitting the underside (belly) of the herring, the Arenco used a set of two horizontal circular knives, which slightly overlapped. The adjustment of the Arenco machine was considered to be finer and tended to reduce the number of improperly cut fish.

The freshly-cut fillets are flumed onto a sorting conveyor where the poorly-cut fillets are separated and repaired manually. Recycled fillets are returned to this conveyor to be again sorted. The good fillets go to a boxing line where they are placed in cartons which are subsequently adjusted for weight and taped closed. The boxes are put onto racks and finally quick frozen.

During spawning season the roe and milt, which are called "spawn," are saved and shipped, respectively, to Japan and England where they are considered delicacies. Production increases as the size of the fish increases; yields of 43 to 45 percent are expected during spawning season. Fillet yields increase in the winter when no roe or milt are present. The fish are generally the larger herring, being 20 to 25 cm (8 to 10 in.) long.

The plant in New England flumed the heads, tails, viscera and other solid wastes to a nearby rendering plant where the solids were recovered and the water discharged. Therefore, no filleting plant wastewater existed except the bailwater, which was discharged. In Alaska the total effluent, including solid wastes, was discharged. The waste flume from the New England plant was sampled to obtain the characteristics of the effluent as if it had been discharged instead of being sent to the reduction plant.

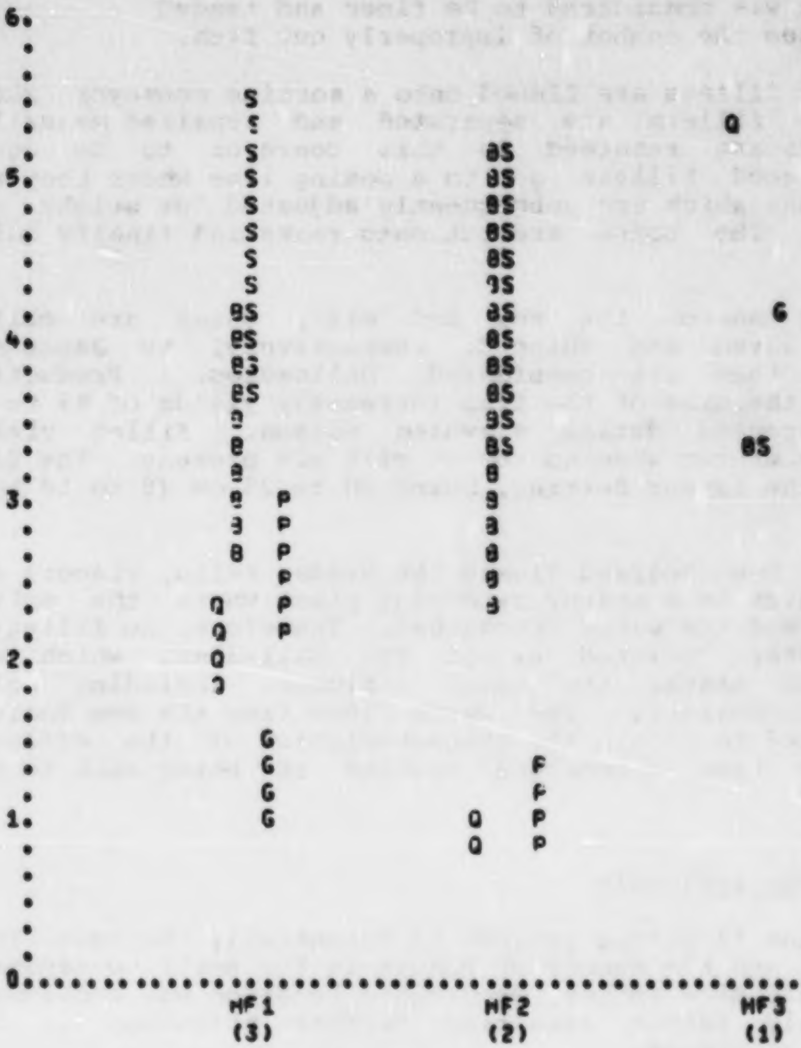
## Subcategorization Rationale

Since the herring filleting process is essentially the same from plant to plant and the number of plants is too small to separate the industry into size ranges, geographic location was considered to be the only factor requiring further attention in the subcategorization process.

Figure 52 summarizes the characteristics of three herring filleting plants. Plant HF1 is located in New England, plant HF2 in the Maritime region of Canada and plant HF3 in Southeastern Alaska. Information on plant HF2 was obtained from a study conducted by the Enviornmental Protection Service of Canada (23).

It was noted that the waste characteristics for all the plants were similar. One difference was the relatively high flow ratio observed at the Alaska plant. This high ratio is not considered to be typical, since the investigation was conducted at the beginning of the season and few fish were being processed. At

Figure 52 . HERRING FILLETING PROCESS PLOT.



| SYMBOL | PARAMETER | SCALING FACTOR |
|---|---|---|
| Q | FLOW | 1 INCH = 5000 L/KKG |
| B | 5 DAY BOD | 1 INCH = 10 KG/KKG |
| S | SUSPENDED SOLIDS | 1 INCH = 5 KG/KKG |
| G | GREASE & OIL | 1 INCH = 5 KG/KKG |
| P | PRODUCTION | 1 INCH = 5 TON/HR |

low processing rates, water use is more independent of production rate.

Table 33 summarizes statistics of the waste loads from all three plants excluding the high flow ratio from the Alaska plant.

One relatively high grease and oil data point at the Alaskan processing facility, resulted in a distorted log normal projection for the grease and oil daily maximum of 86.6 kg per kkg of raw material, i.e., over 8 percent of the weight of raw material. Since the typical fat composition of herring ranges from 2 up to 11 percent of body weight, it would be unlikely for 78 percent or more of this fat to reach the waste water effluent stream because a major proportion of the fat is contained in the food product and waste solids. A comparison of the mechanically butchered salmon processing raw waste load to the mechanical herring filleting raw waste load indicates that TSS averages are virtually identical, 20.3 kg/kkg for salmon and 20.9 kg/kkg for herring filleting; the salmon $BOD_5$ waste load is higher, 50.8 kg/kkg for salmon versus 32.2 kg/kkg for herring filleting; the salmon grease and oil average is also virtually identical to the average for the New England herring filleting plant, 6.49 kg/kkg for salmon versus 6.11 kg/kkg for New England herring filleting. Because the one data point at the Alaskan herring filleting plant appeared to be highly questionable in comparison to the other available information, it was not used to determine a subcategory average. Instead, the mechanical salmon process grease and oil data was utilized to derive conclusions regarding effluent limitations for the herring filleting process plants.

## Clams

The processing of clams for fresh or frozen meat or for a canned product was considered to be a moderately important segment of the seafood industry because of the relatively large number of plants engaged in this activity. The industry produces wastewater flows and loadings which are quite variable and plant sizes vary widely. Therefore, a total of eight processing operations were investigated and a total of 38 unit operation and end-of-pipe composite samples of the wastewater collected. Although three important types of clams are processed (surf, hard, and soft), only surf clam processes were sampled since these are, by far, the most important, in terms of production and wastes generated. Plants processing hard and soft clams were visited and information on the processing methods was obtained.

## Process Description

The process description for surf clams is discussed in detail since it is the most important. The processing of hard and soft clams is basically the same as surf clam processing, except that higher percentages are handled manually.

Table 33

## HERRING FILLET
## PROCESS SUMMARY OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION* | | | | |
| (TON/HR) | 5.92 | | 6.46 | |
| TIME* | | | | |
| (HR/DAY) | 5.11 | | 2.70 | |
| FLOW* | | | | |
| (L/SEC) | 19.6 | | 19.8 | |
| (GAL/MIN) | 310. | | 313. | |
| FLOW RATIO** | | | | |
| (L/KKG) | 7020. | 8.856 | 0.538 | 24600. |
| (GAL/TON) | 1680. | 7.428 | 0.538 | 5890. |
| TSS** | | | | |
| (MG/L) | 2970. | 7.997 | 0.185 | 4570. |
| (KG/KKG) | 20.9 | 3.038 | 0.185 | 32.1 |
| BOD-5** | | | | |
| (MG/L) | 4600. | 8.433 | 0.061 | 5300. |
| (KG/KKG) | 32.2 | 3.474 | 0.061 | 37.2 |
| GREASE AND OIL**[1] | | | | |
| (MG/L) | 924. | 6.83 | 0.605 | 3790. |
| (KG/KKG) | 6.49 | 1.87 | 0.605 | 26.5 |
| PH* | 6.66 | | | |

PLANTS HF1 ,HF2 ,HF3

* THE OUTPUT FOR THESE PARAMETERS
ARE THE NORMAL (UNWEIGHTED) MEAN
AND STANDARD DEVIATION, RESPECTIVELY

** THE OUTPUT FOR THESE PARAMETERS
ARE THE LOG NORMAL (UNWEIGHTED) MEAN
AND STANDARD DEVIATION, RESPECTIVELY

[1] Because the grease and oil data at the Alaskan herring filleting plant was highly questionable in comparison to other available information, it was not used to determine a subcategory average. Instead, the mechanized salmon grease and oil data was utilized to derive the summary data for the herring filleting process.

The surf clam process consists of three basic operations: shucking, debellying, and packing. Most plants produce frozen or chilled clam meat which is shipped to other areas for further processing into soup, chowder, or a canned meat product. Some plants include a canning operation with the meat operation.

Shucking of the clam involves removal of the organism from the shell and is accomplished either manually or mechanically. Mechanized operations are usually large and the manual operations small.

Since more waste is generated in the mechanized operations, they were investigated in greater detail. Figure 53 shows a typical mechanized surf clam process including shucking, debellying, and the three observed methods of packing. The figure also includes an evaporated juice operation which is used in some processes.

The clams are unloaded from the vessels in heavy wire cages and conveyed into the plant where they may receive a preliminary wash before shucking. The washing is accomplished by a spray onto the belt or by a reel washer. The reel washer is cylindrical, ranges from 1 to 1.5 m (3 to 5 ft) in diameter and 2 to 3.5 m (6 to 12 ft) in length and is usually made of stainless steel. Two basic types of reel washers are in use: one is partially submerged in a "V" shaped stainless steel tank filled with water; the other type is suspended above the same type of tank, which in this case serves as a drain for water sprayed from a perforated pipe within the drum itself.

Heating the clams can be effected using a "shucking furnace," steam cooker, or hot water cooker. The shucking furnace, also known as a shucking machine or the "iron man," is a large propane furnace reaching temperatures from 625°C to 815°C (1160°F to 1500°F). A heavy metal chain belt transports the clams through the iron man in 50 to 100 seconds, depending upon the internal temperature.

The steam cooker method operates at 2 atm (15 psig) for one to two minutes at a temperature of 132°C (270°F). The liquid generated is piped off and condensed for use as clam broth. The condenser water may be recycled and used in the first washer. The hot water cooker method immerses the clams in water at a temperature of approximately 82°C (180°F) for one to two minutes. This method is most typical in hand-shucked operations.

After heating, the clams are usually washed using one or more reel washers. The meat is then removed from the shell, most often by the use of a brine flotation tank. Occasionally a hammer mill grinder or a shaker is used ahead of the flotation tank to help separate the meat from the shell. Any meat still attached to the shells is removed by hand and placed in a reel washer which follows the shucking operation. Some operations will repeat the last two steps; i.e., brine flotation, then washing. The shells are stockpiled, and utilized in landfills or

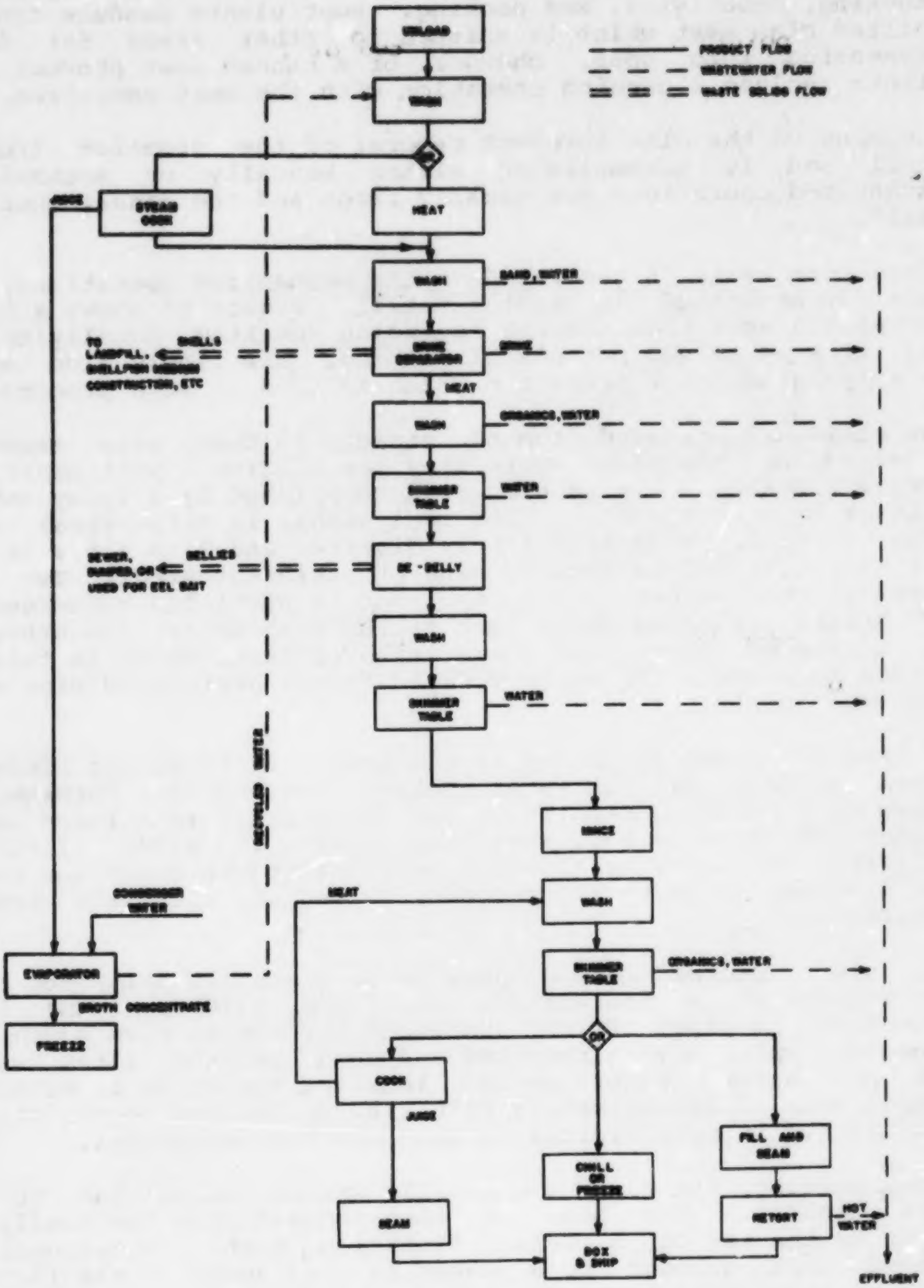

UNLOAD
PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
WASH
OR
JUICE
STEAM COOK
HEAT
WASH
SAND, WATER
TO LANDFILL, SHELLFISH [illegible] CONSTRUCTION, ETC
SHELLS
BRINE SEPARATOR
BRINE
HEAT
WASH
ORGANICS, WATER
SKIMMER TABLE
WATER
SEWER, DUMPED, OR USED FOR EEL BAIT
BELLIES
DE-BELLY
WASH
SKIMMER TABLE
WATER
RECYCLED WATER
MINCE
CONDENSER WATER
HEAT
WASH
EVAPORATOR
SKIMMER TABLE
ORGANICS, WATER
BROTH CONCENTRATE
FREEZE
OR
COOK
JUICE
FILL AND SEAM
CHILL OR FREEZE
SEAM
RETORT
HOT WATER
BOX & SHIP
EFFLUENT

Figure 53. Typical mechanized surf clam process.

road construction, or piled to dry for subsequent use as media for shellfish larval attachment.

At this point, the meats are belted or flumed across a "skimmer table" to the debellying operation. A few plants fresh pack the whole clams and ship them to other areas for further processing, but this is not typical. The clam belly is usually removed manually, however, this step is becoming automated in many plants. The viscera and gonads removed from the surf clam are dumped directly into the adjacent waters, ground and discharged to the local sewer system, or recovered for bait or animal food.

Only the adductor muscles and the muscle tissue of the foot and mantle edge of the clam continue on to the next washer, which may be a reel washer, a circular jet washer, or an air blow washer. The circular jet washer is a doughnut-shaped tub with tangential nozzles on the bottom to create a strong circular current in about 10 cm (4 in.) of water. A small opening allows a constant overflow of clams. Air blow washers are large "V" shaped stainless steel tanks. Air is bubbled the entire length of the tank from the bottom through the smaller trough, agitating the clams. In addition, an auger creates a current which helps to clean and move the clams along.

After being washed, the clams normally pass over a skimmer table. Depending upon the desired end product, the clams are then either fresh packed as whole clams, or chopped or minced for further processing.

Three methods of further processing of the minced clams were observed: chilling or freezing, canning, and cooking for juice. Little waste is generated by the chilling or freezing or canning operations. When the clam juice is evaporated, the waste load is increased, due to volatiles being entrained in the condenser water.

Figure 54 illustrates the product and waste flow for a typical hand-shucked surf clam process. The clams arrive by boat or truck in wire cages holding about 32 bushels per cage. The clams are belted through a spray washer and into a hot water blancher which partially opens the clams. Residence time in the blancher, which operates at about 80°C (176°F) is approximately twenty seconds. The clams are next belted to a shucking table where the meat is removed manually by prying the shell open and scraping it with a knife. The meats are transported by bucket to a reel washer where sand is removed. After the clams pass through the washer, they are again put into buckets and taken to a debellying and inspection table where the bellies and pieces of shell and other extraneous matter that may be clinging to the clam meats are removed by hand. The clam bellies are stored in barrels and used for bait or animal food or simply discarded. The clam meats are placed into a jet washer, as described previously, which removes most of the remaining bits of sand and shell. From the jet washer they pass onto a table with perforations (skimmer

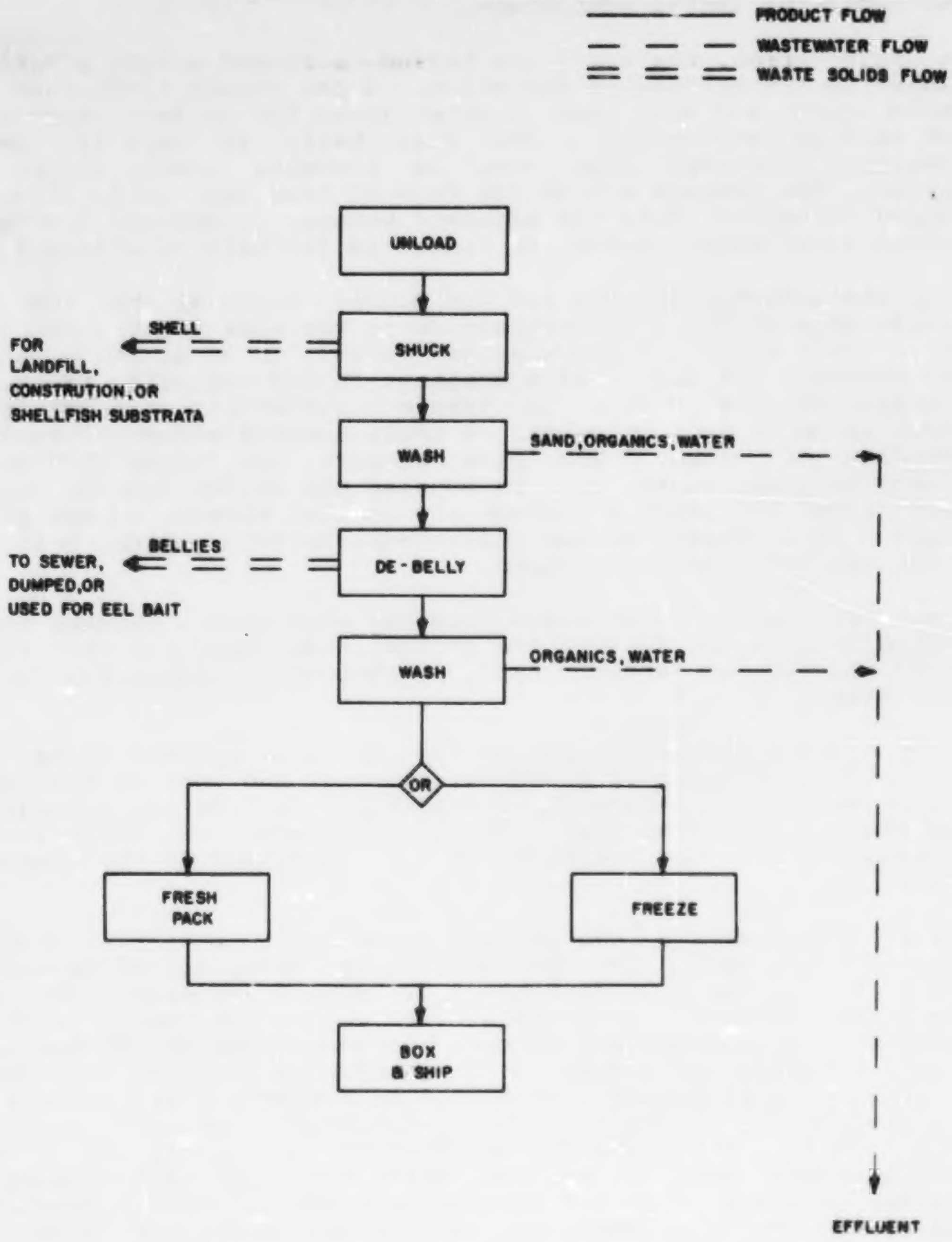

PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
UNLOAD
SHUCK
SHELL
FOR LANDFILL, CONSTRUTION, OR SHELLFISH SUBSTRATA
WASH
SAND, ORGANICS, WATER
DE-BELLY
BELLIES
TO SEWER, DUMPED, OR USED FOR EEL BAIT
WASH
ORGANICS, WATER
OR
FRESH PACK
FREEZE
BOX & SHIP
EFFLUENT

Figure 54. Typical hand-shucked surf clam process.

table) which drains most of the water and where more shell is manually removed. From this table they pass into the second reel washer for final cleaning. The washed meat is then either fresh-packed or frozen.

The processing of hard and soft clams is similar to a handshucked oyster process. The clam is shucked manually, washed and packed. Hard clams have a larger frozen shelf life than other clams so they are usually frozen. A few hard clams are also sold fresh for chowder and some are sold in the shell. The soft clam is usually fresh-packed and shipped elsewhere for further processing. Some soft clams are also sold in the shell or used as bait.

Some conchs are harvested along with clams and are often processed in the same plant. In a typical operation, the meat is manually separated from the shell and the viscera removed. The meat is then washed, chopped and canned. Clam juice and salt is added before canning. Conch shells in good condition are sold for souvenirs. The remaining shells are discarded, like clam shells, in landfills or road construction.

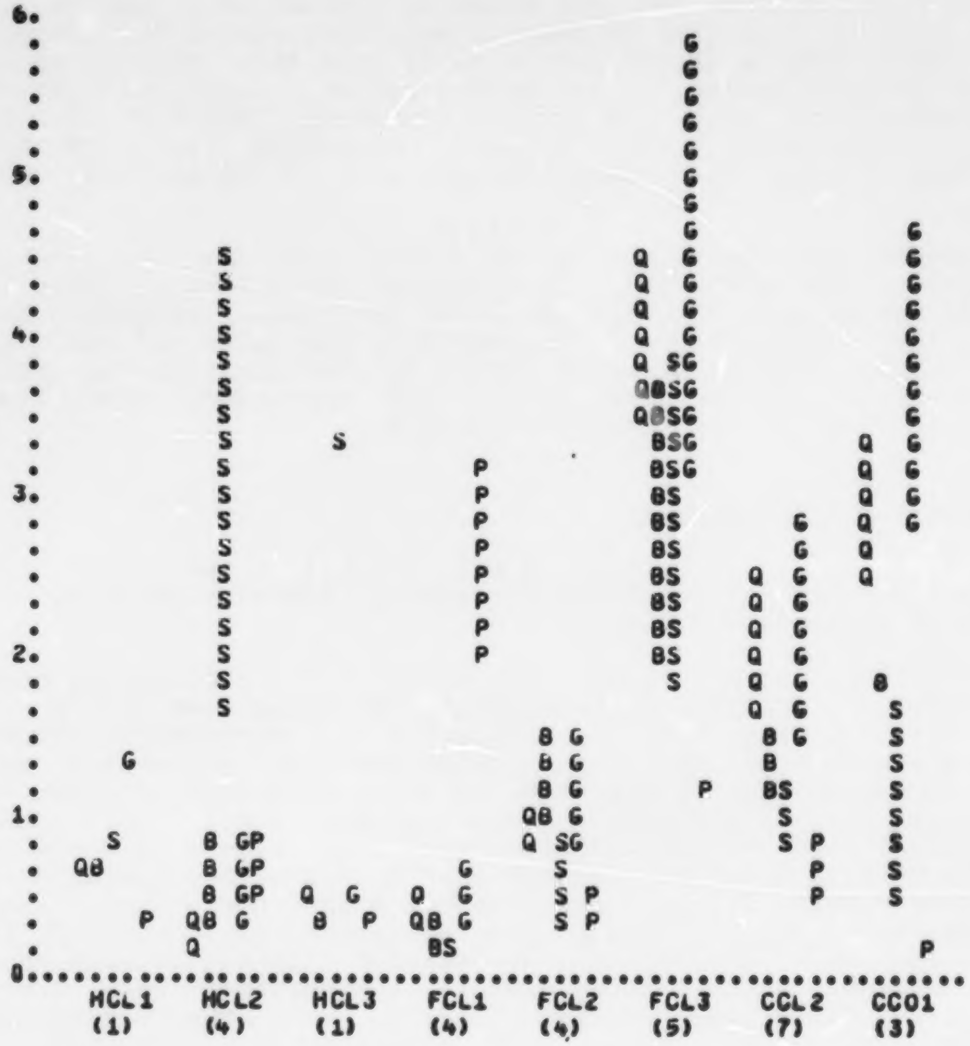
## Subcategorization Rationale

Although there is a variety of clam processing operations, the only factor which is considered to affect subcategorization is the degree of mechanization.

A conventional clam process is defined as one where the unit operations are performed essentially by hand and with a relatively low water flow. A mechanized clam process is defined as one where most of the unit operations are mechanized and where, consequently, water flow is relatively high. Figure 55 summarizes the wastewater characteristics for both the conventional and mechanized clam processes. Plants represented by codes HCL1, 2 and 3 are conventional hand-shucking operations, while plants FCL1, 2, 3 and CCl2 are mechanized operations. Code CCO1 represents a conch canning process, which is conducted in conjunction with a clam canning operation. It can be seen that the conventional hand-shucking operations contribute much lower wastewater flows and organic loadings than the mechanized operations.

The data from the three conventional plants are relatively uniform; however, a greater range in the data from the mechanized plants are evident. The plant with code FCL1 shucked but did not debelly the clams, resulting in lower waste loads. The plant with code FCL3 was a highly mechanized plant with very high water use due to considerable washing of the product. Plant FCL3 also steam cooked the clams to facilitate shucking and condensed the clam juice, leading to higher waste loads due to evaporator condensate.

Figure 55. CONVENTIONAL OR MECHANIZED CLAM PROCESS PLOT.



| SYMBOL | PARAMETER | SCALING FACTOR |
|---|---|---|
| Q | FLOW | 1 INCH = 10000 L/KKG |
| B | 5 DAY BOD | 1 INCH = 10 KG/KKG |
| S | SUSPENDED SOLIDS | 1 INCH = 5 KG/KKG |
| G | GREASE & OIL | 1 INCH = 0.2 KG/KKG |
| P | PRODUCTION | 1 INCH = 10 TON/HR |

All the conventional clam operations were included in one subcategory; all the mechanized clam operations were included in another subcategory for the above reasons.

Table 34 summarizes the waste parameters from the conventional clam plants. The large standard deviation of suspended solids was caused by the highly variable nature of the sand content in the effluent, especially during washdown.

Table 35 summarizes the waste parameters from the mechanized clam plants. Plant FCL1 was not included, since it was a hybrid operation and did not include the debellying operation. Plant CCL2 was not included because it utilized a manual debelling unit operation.

## OYSTERS

The processing of oysters for fresh or frozen meat or for a canned product was considered to be a moderately important segment of the seafood industry due to the large number of plants engaged in this activity. The industry uses both conventional and mechanized techniques, which result in a wide range of wastewater flows and organic loadings. In addition, plant sizes vary widely. Therefore, a total of 14 processing operations were investigated and a total of 99 unit operation and end-of-pipe composite samples of wastewater collected.

### Process Description

The processing of oysters consists of two basic operations: shucking and packing. The oyster process is less complicated than the surf clam process, since oyster viscera are not removed. Most plants produce fresh or frozen meat, while some produce a canned meat or canned stew.

Shucking of the oyster is accomplished using either manual or mechanical methods, although manual operations are more prevalent. Mechanized operations are generally large, while manual operations range from very small to moderately large.

Since more waste is generated in the mechanized operations, these were investigated in some detail. Figure 56 depicts a typical mechanized process, referred to as the steamed or canned oyster process, as observed in the Middle Atlantic and Northwest regions. Unfortunately, the oyster canning season had not started in the Gulf before the end of the sampling program; therefore, no operations were investigated in that region. However, the same species and same processing methods are utilized in both the Gulf and Middle Atlantic regions.

The oysters arrive at the plant in wire cages and are conveyed into the plant as needed, to two sequential drum washers. The first washer cleans the oyster shells, and removes broken shell,

Table 34

## HAND-SHUCKED CLAM
## PROCESS SUMMARY OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION* | | | | |
| (TON/HR) | 4.68 | | 1.64 | |
| TIME* | | | | |
| (HR/DAY) | 4.60 | | 2.01 | |
| FLOW* | | | | |
| (L/SEC) | 5.36 | | 2.06 | |
| (GAL/MIN) | 85.0 | | 32.7 | |
| FLOW RATIO** | | | | |
| (L/KKG) | 4570. | 8.427 | 0.618 | 19300. |
| (GAL/TON) | 1100. | 6.998 | 0.618 | 4620. |
| TSS** | | | | |
| (MG/L) | 2240. | 7.716 | 0.749 | 12900. |
| (KG/KKG) | 10.2 | 2.327 | 0.749 | 58.7 |
| BOD-5** | | | | |
| (MG/L) | 1130. | 7.026 | 0.321 | 2380. |
| (KG/KKG) | 5.14 | 1.638 | 0.321 | 10.9 |
| GREASE AND OIL** | | | | |
| (MG/L) | 31.7 | 3.457 | 0.579 | 122. |
| (KG/KKG) | 0.145 | -1.932 | 0.579 | 0.558 |
| PH* | 6.99 | | | |

PLANTS HCL1 ,HCL2 ,HCL3

* THE OUTPUT FOR THESE PARAMETERS ARE THE NORMAL (UNWEIGHTED) MEAN AND STANDARD DEVIATION, RESPECTIVELY

** THE OUTPUT FOR THESE PARAMETERS ARE THE LOG NORMAL (UNWEIGHTED) MEAN AND STANDARD DEVIATION, RESPECTIVELY

## Table 35

## MECHANIZED CLAM
## PROCESS SUMMARY OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION* | | | | |
| (TON/HR) | 8.44 | | 5.03 | |
| TIME* | | | | |
| (HR/DAY) | 7.30 | | 0.283 | |
| FLOW* | | | | |
| (L/SEC) | 67.4 | | 77.7 | |
| (GAL/MIN) | 1070. | | 1230. | |
| FLOW RATIO** | | | | |
| (L/KKG) | 19500. | 9.880 | 1.011 | 206000. |
| (GAL/TON) | 4680. | 8.451 | 1.011 | 49400. |
| TSS** | | | | |
| (MG/L) | 325. | 5.784 | 1.138 | 4610. |
| (KG/KKG) | 6.35 | 1.849 | 1.138 | 90.0 |
| BOD-5** | | | | |
| (MG/L) | 958. | 6.865 | 0.605 | 3920. |
| (KG/KKG) | 18.7 | 2.929 | 0.605 | 76.6 |
| GREASE AND OIL** | | | | |
| (MG/L) | 23.6 | 3.162 | 0.953 | 218. |
| (KG/KKG) | 0.461 | -0.774 | 0.953 | 4.25 |
| PH* | 6.79 | | | |

PLANTS FCL2 ,FCL3

* THE OUTPUT FOR THESE PARAMETERS ARE THE NORMAL (UNWEIGHTED) MEAN AND STANDARD DEVIATION, RESPECTIVELY

** THE OUTPUT FOR THESE PARAMETERS ARE THE LOG NORMAL (UNWEIGHTED) MEAN AND STANDARD DEVIATION, RESPECTIVELY

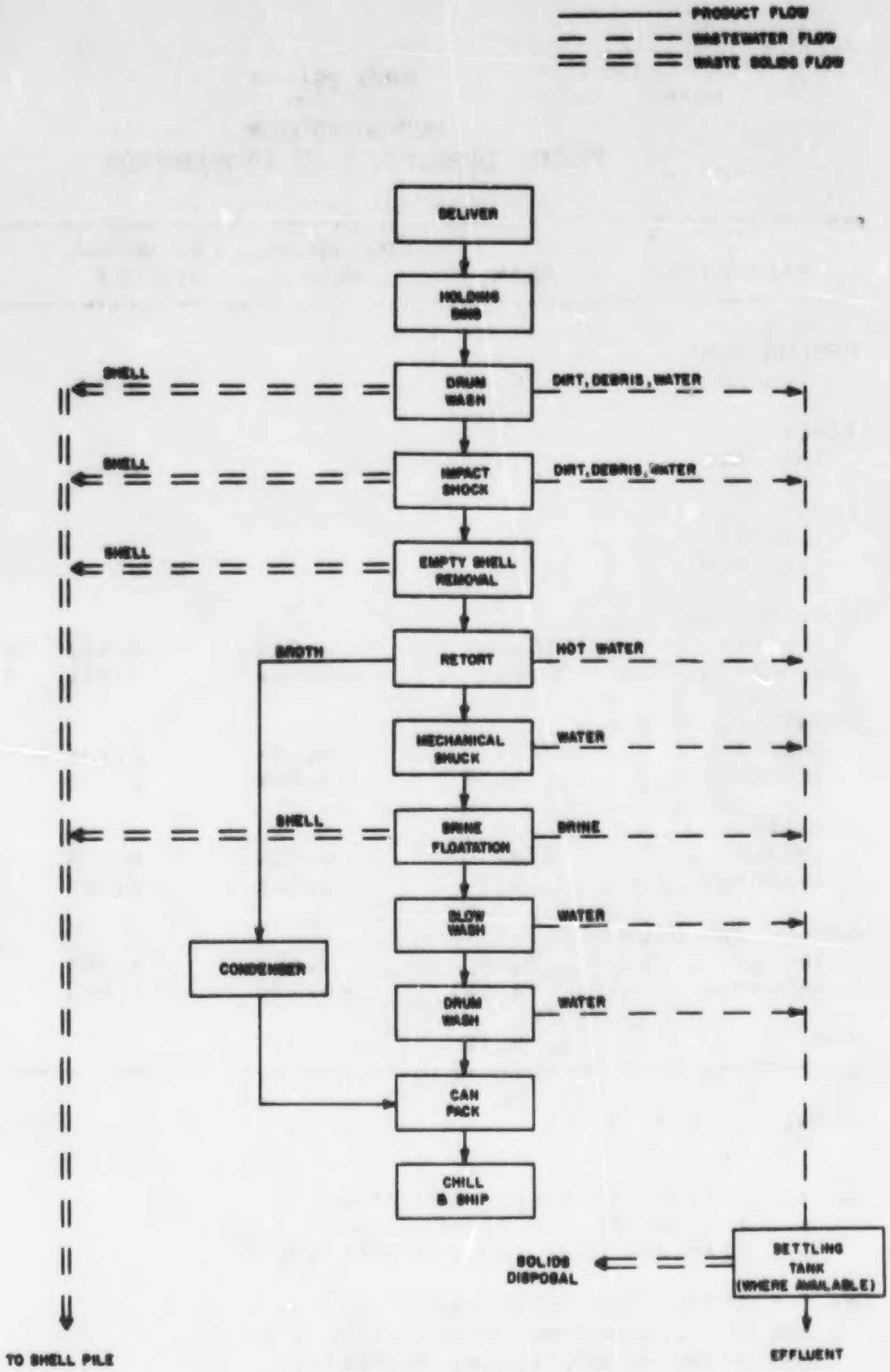

PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
DELIVER
HOLDING BINS
SHELL
DRUM WASH
DIRT, DEBRIS, WATER
SHELL
IMPACT SHOCK
DIRT, DEBRIS, WATER
SHELL
EMPTY SHELL REMOVAL
BROTH
RETORT
HOT WATER
MECHANICAL SHUCK
WATER
SHELL
BRINE FLOATATION
BRINE
BLOW WASH
WATER
CONDENSER
DRUM WASH
WATER
CAN PACK
CHILL & SHIP
SOLIDS DISPOSAL
SETTLING TANK (WHERE AVAILABLE)
TO SHELL PILE
EFFLUENT

Figure 56. Typical steamed or canned oyster process.

seaweed, and other matter. The second washer has a different pitch and serves to jar the valves far enough apart to allow steam to enter during the cooking. Loose empty shells are manually removed before the oysters are collected in retort baskets. The oysters are steamed in retorts under pressure and the resulting oyster juice or broth piped to a holding tank and later condensed. After cooking, the meat is separated from the shell manually or by brine flotation. One mechanized method uses a specially designed drum washer called the "shucker". This serves to mechanically separate the meat from the shell as the drum rotates. Both the meat and the shell are collected in a brine flotation tank where the buoyancy of the meats allows the saturated salt solution to float them to a blow tank which agitates and adds water to the product. The shells sink to the bottom of the brine tank, where a belt collects them and deposits them outside the plant. The meats go through a final drum washer before being manually inspected. The oyster meat at this point may be fresh packed in large cans, together with the condensed broth, or canned and retorted. Some oysters are also smoked prior to packing in jars or tins.

Figure 57 shows a typical conventional hand-shucked oyster process as observed on both the East and West Coasts. The oysters are shucked manually and usually fresh packed, although some are breaded and some cooked for stew. The oysters arrive at the plant by boat, barge, or truck and are conveyed into the plant on a belt or in buckets. The shells may be washed to remove most of the mud, and to facilitate shucking. Shuckers open the shells manually by forcing the valves apart and cutting the adductor muscle. The meat is put into buckets, washed on a skimmer table and placed in the blow washer. The blow washer typically holds about 300 liters (80 gal.) of water. For the first 5 to 15 minutes air is bubbled through the washer; for the following 20 to 50 minutes, overflow water is added to the tanks. The oysters are dewatered on a skimmer table and then packed in cans. A few operations bread and freeze the oysters, which adds an additional waste load during washdown.

A few plants sort out the broken oyster pieces and can them as a stew. This is a minor operation and occurs only once or twice per week depending on the supply of pieces. The oysters are first cooked in large vats for about 30 minutes, along with pieces and preservatives. The meat is then rinsed and added to the cans, along with milk and broth. The can is then sealed and retorted.

## Subcategorization Rationale

The only factors which were considered to affect subcategorization of the oyster industry were the degree of mechanization and geographic location. Figure 58 summarizes the wastewater parameter statistics for all the oyster processes sampled. Plants represented by codes HS01 through HS06 were East Coast

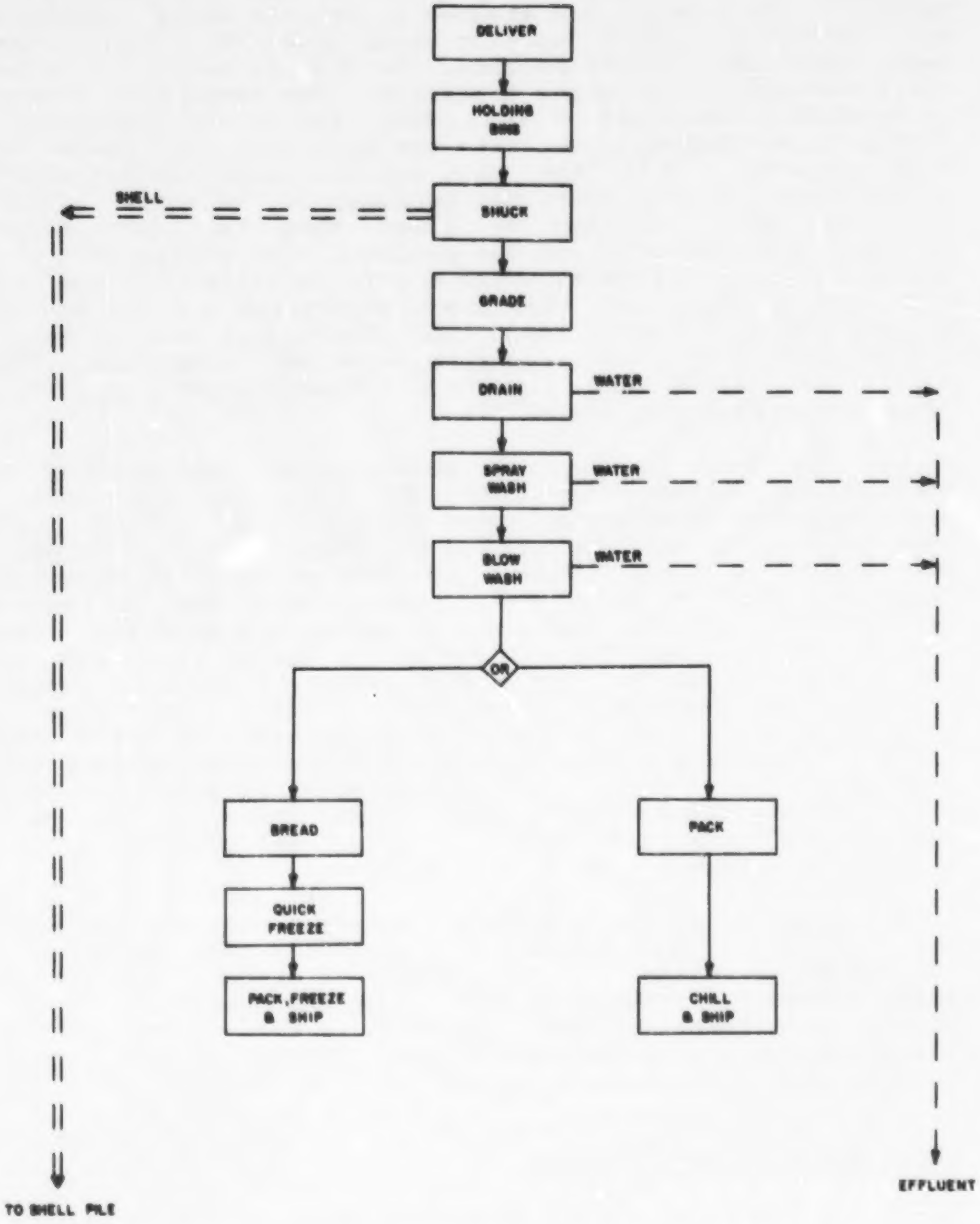
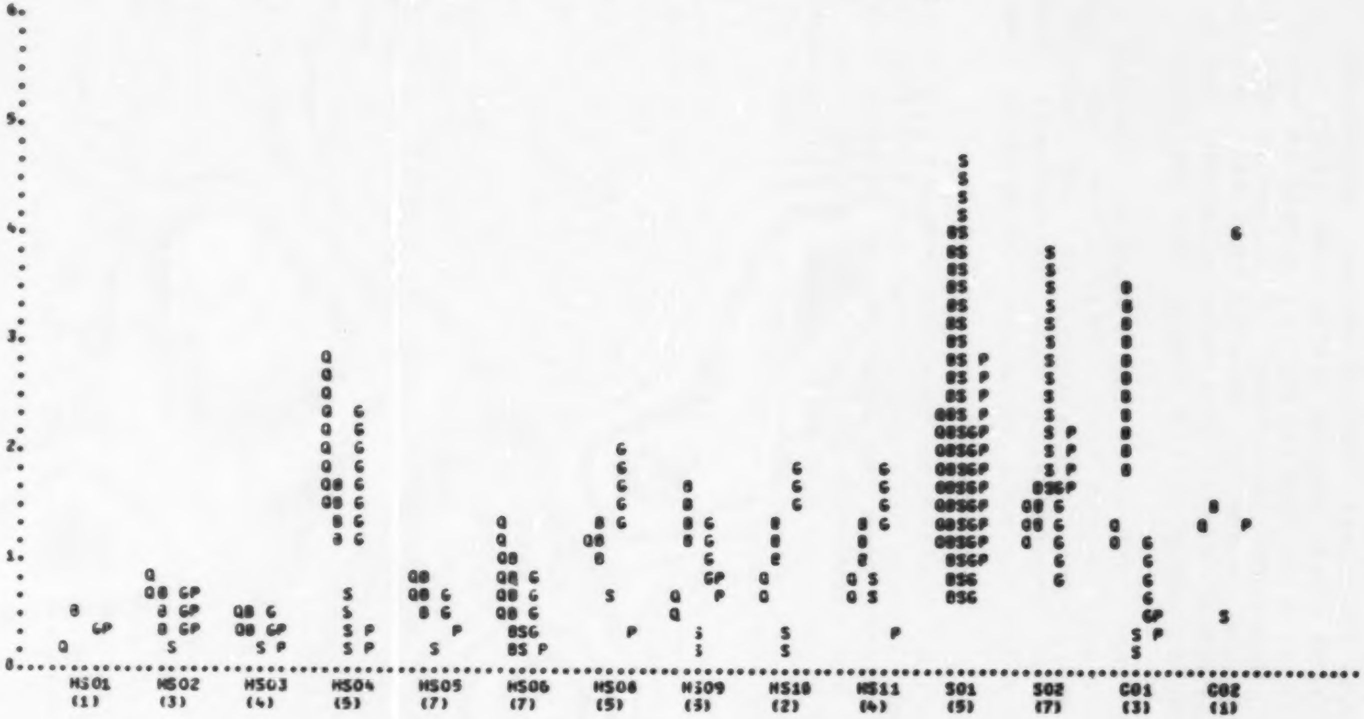

DELIVER
HOLDING BINS
SHELL
SHUCK
GRADE
DRAIN
WATER
SPRAY WASH
WATER
BLOW WASH
WATER
OR
BREAD
PACK
QUICK FREEZE
PACK, FREEZE & SHIP
CHILL & SHIP
TO SHELL PILE
EFFLUENT

Figure 57. Typical hand-shucked oyster process.

Figure 58. FRESH/FROZEN, STEAMED, OR CANNED OYSTER PROCESS PLOT.



| SYMBOL | PARAMETER | SCALING FACTOR |
|---|---|---|
| Q | FLOW | 1 INCH = 50000 L/KKG |
| B | 5 DAY BOD | 1 INCH = 20 KG/KKG |
| S | SUSPENDED SOLIDS | 1 INCH = 50 KG/KKG |
| G | GREASE AND OIL | 1 INCH = 1 KG/KKG |
| P | PRODUCTION | 1 INCH = 0.5 TON/HR |

hand-shucked oyster operations; plants represented by codes HS08 through HS11 were West Coast hand-shucked oyster operations; codes S01 and S02 represent steamed oyster processes; Code C01 represents a West Coast canned oyster operation; and C02 a West Coast canned oyster stew operation. It should be noted that the production is expressed in terms of weight of the oyster meat after shucking. The reason for this is that the measurement of final product in this case is much more accurate, due to variable amounts of loose or empty shells coming into the plant.

It was noted that the waste loads from the steamed and canned oyster processes were higher than those from the hand-shucked fresh/frozen operations. Therefore, it was decided that the oyster industry be subcategorized into conventional hand-shucked oyster processes and the more mechanized steamed or canned oyster processes.

Table 36 summarizes statistics from the steamed and canned oyster plants sampled, S01 and S02, and historical data from plant SOV. Plant S03 was deleted from the subcategory average because the raw material was prewashed before entering the plant. The data from plant SOV represents a steamed/canned oyster process in the Gulf Coast area. It was assumed that the waste loads per unit of production were independent of plant size.

It also appears that the waste loads from the West Coast hand-shucked oyster processes were somewhat higher than those from the East Coast processes. This probably was due to the fact that the West Coast oyster is larger and tends to "break up" easier during handling. Therefore, the hand-shucked oysters were divided into two subcategories: West Coast hand-shucked oyster processing and East and Gulf Coast hand-shucked oyster processing.

Table 37 summarizes statistics from the Pacific hand-shucked oyster plants sampled. Table 38 summarizes statistics from the East Coast hand-shucked oyster plants sampled. However flow ratio data from plants HS04 and HS06 were omitted because of excessive overflows from the oyster blow tanks. It was assumed that the waste loads per unit of production were independent of plant size, because there is no apparent relationship or trend relating flow ratios, TSS ratios, or BOD5 ratios to production levels (See Figures 59 through 64).

Since the size range of the hand-shucked oyster industry is quite large, it was divided into three parts for the purpose of determining treatment costs. Based on investigations made in the field the large and medium-size ranges were divided at 300 tons of finished product per year, and the medium and small ranges at 150 tons of finished product per year.

## SCALLOPS

## Table 38

## STEAMED/CANNED OYSTER
## PROCESS SUMMARY OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION* | | | | |
| (TON/HR) | 0.712 | | 0.392 | |
| TIME* | | | | |
| (HR/DAY) | 10.7 | | 5.17 | |
| FLOW* | | | | |
| (L/SEC) | 13.3 | | 2.45 | |
| (GAL/MIN) | 211. | | 38.8 | |
| FLOW RATIO** | | | | |
| (L/KKG) | 98200. | 11.495 | 0.476 | 298000. |
| (GAL/TON) | 23500. | 10.066 | 0.476 | 71400. |
| TSS** | | | | |
| (MG/L) | 1580. | 7.364 | 0.234 | 2720. |
| (KG/KKG) | 155. | 5.044 | 0.234 | 267. |
| BOD-5** | | | | |
| (MG/L) | 624. | 6.435 | 0.887 | 4930. |
| (KG/KKG) | 61.2 | 4.115 | 0.887 | 484. |
| GREASE AND OIL** | | | | |
| (MG/L) | 15.1 | 2.715 | 0.180 | 23.0 |
| (KG/KKG) | 1.48 | 0.395 | 0.180 | 2.26 |
| PH* | 7.12 | | . | |

PLANTS S01 ,S02 ,S0V

* THE OUTPUT FOR THESE PARAMETERS ARE THE NORMAL (UNWEIGHTED) MEAN AND STANDARD DEVIATION, RESPECTIVELY

** THE OUTPUT FOR THESE PARAMETERS ARE THE LOG NORMAL (UNWEIGHTED) MEAN AND STANDARD DEVIATION, RESPECTIVELY

## Table 37

### WEST COAST HAND SHUCKED OYSTERS
### PROCESS SUMMARY
### OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION (TON/HR)* | 0.179 | | 0.146 | |
| TIME (HR/DAY)* | 7.06 | | 1.56 | |
| FLOW (L/SEC)* | 1.69 | | 1.05 | |
| (GAL/MIN)* | 26.9 | | 16.6 | |
| FLOW RATIO (L/KKG) | 55300 | 10.9 | 0.007 | 56100 |
| (GAL/TON) | 13300 | 9.49 | 0.007 | 13400 |
| TSS (MG/L) | 620 | 6.43 | 0.029 | 661 |
| (KG/KKG) | 34.2 | 3.53 | 0.029 | 36.6 |
| BOD-5 (MG/L) | 432 | 6.07 | 0.018 | 450 |
| (KG/KKG) | 23.9 | 3.17 | 0.018 | 24.9 |
| GREASE AND OIL (MG/L) | 28.1 | 3.34 | 0.036 | 30.5 |
| (KG/KKG) | 1.55 | 0.442 | 0.036 | 1.69 |
| PH* | 6.82 | | 0.155 | |

PLANTS WS09,WS05,WS10,WS11

* NOTE: THE OUTPUTS FOR THESE PARAMETERS ARE THE NORMAL (UNWEIGHTED) MEAN AND STANDARD DEVIATION, RESPECTIVELY

## Table 38

### EAST AND GULF COAST HAND SHUCKED OYSTERS
### PROCESS SUMMARY
### OF SELECTED PARAMTERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION (TON/HR)* | 0.147 | | 0.085 | |
| TIME (HR/DAY)* | 6.21 | | 1.11 | |
| FLOW (L/SEC)* | 1.69 | | 0.988 | |
| (GAL/MIN)* | 26.9 | | 15.7 | |
| FLOW RATIO (L/KKG) | 32600 | 10.4 | 0.029 | 34800 |
| (GAL/TON) | 7820 | 8.96 | 0.029 | 8350 |
| TSS (MG/L) | 416 | 6.03 | 0.143 | 579 |
| (KG/KKG) | 13.6 | 2.61 | 0.143 | 18.9 |
| BOD-5 (MG/L) | 455 | 6.12 | 0.075 | 541 |
| (KG/KKG) | 14.9 | 2.70 | 0.075 | 17.7 |
| GREASE AND OIL (MG/L) | 20.4 | 3.01 | 0.066 | 23.7 |
| (KG/KKG) | 0.665 | -0.410 | 0.066 | 0.775 |
| PH* | 7.09 | | 0.012 | |

PLANTS HS02,HS03,HS04,HS05,HS06

* NOTE: THE OUTPUTS FOR THESE PARAMETERS
ARE THE NORMAL (UNWEIGHTED) MEAN
AND STANDARD DEVIATION, RESPECTIVELY

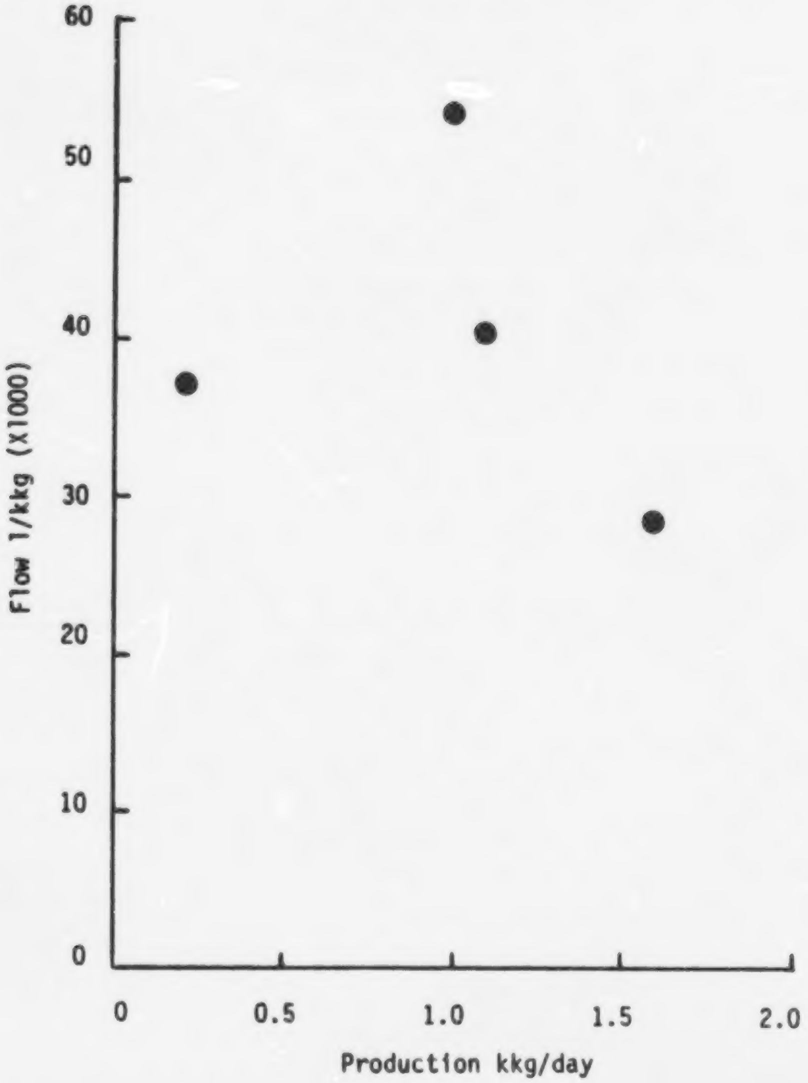


Figure 59
West Coast oyster flow ratios versus production level

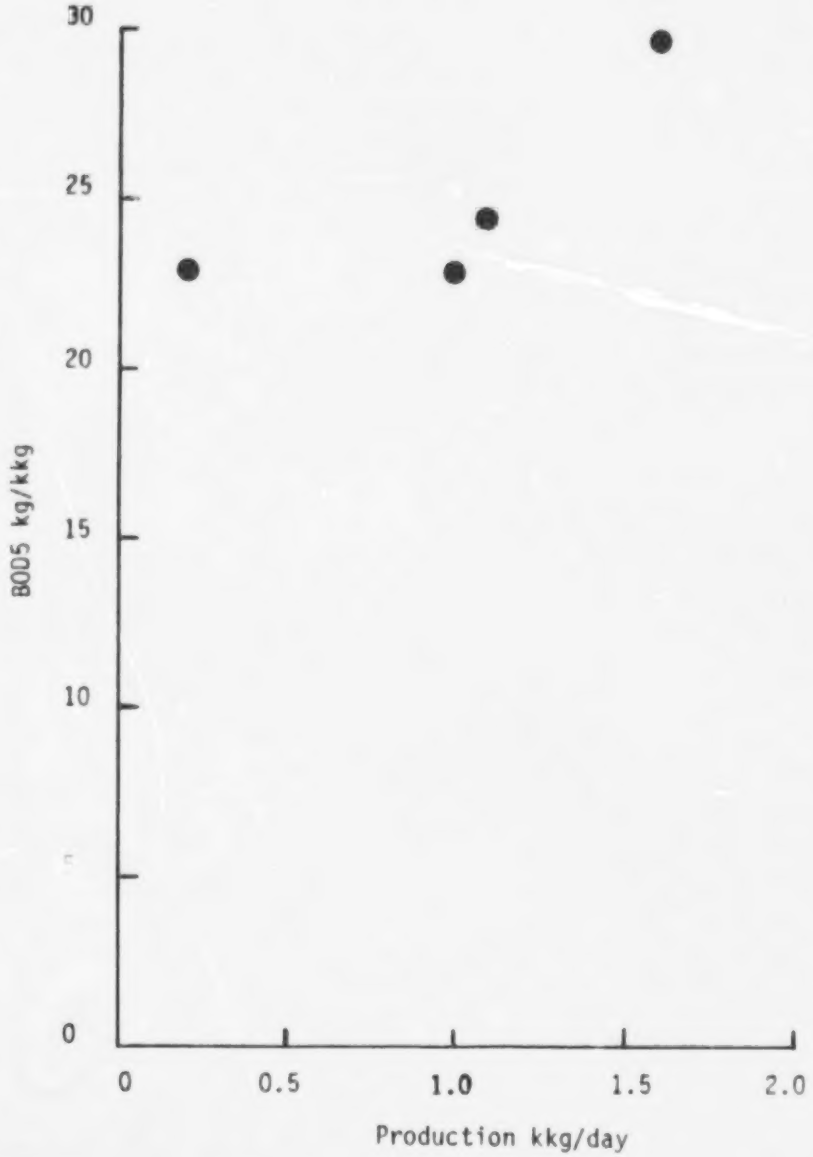


Figure 60
West Coast oyster BOD5 ratios
versus production level

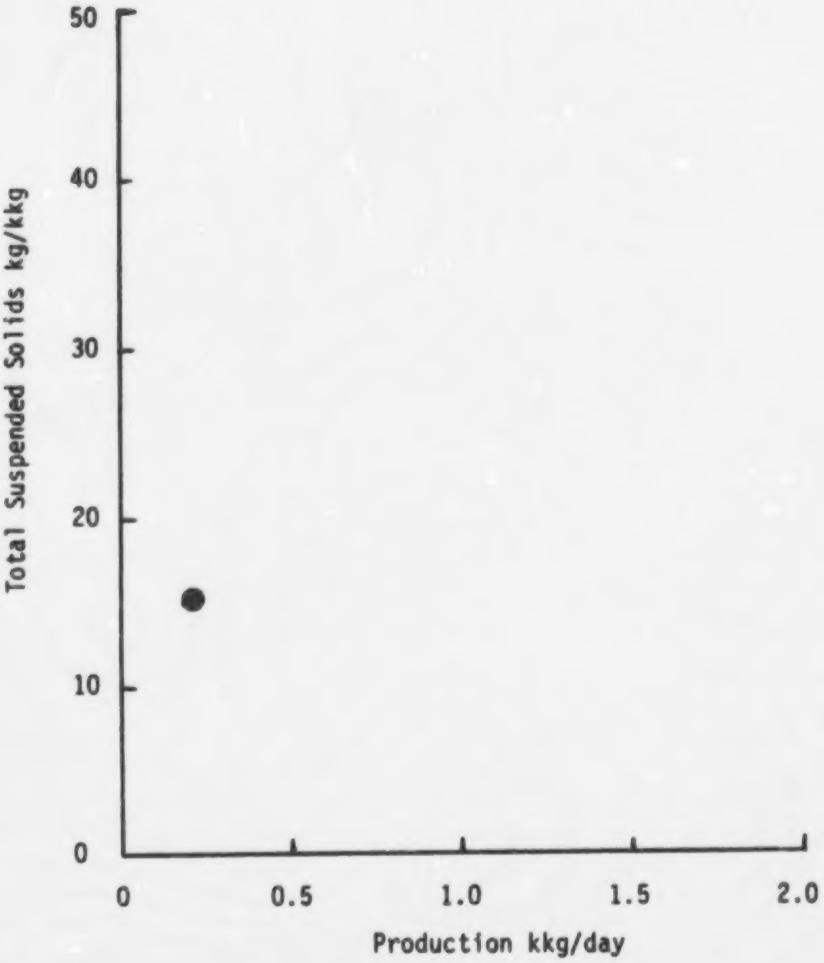


Figure 61
West Coast oyster total suspended solids ratios versus production level

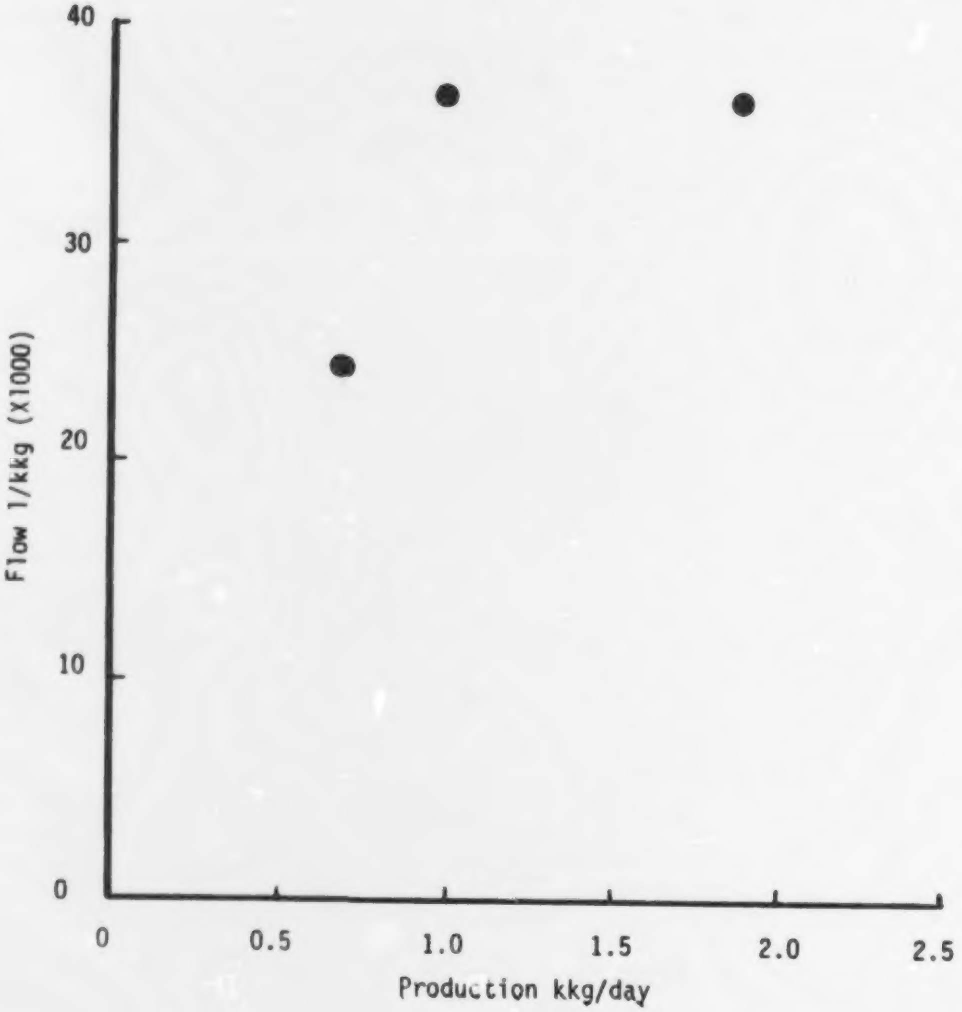


Figure 62
East Coast oyster flow ratios
versus production level

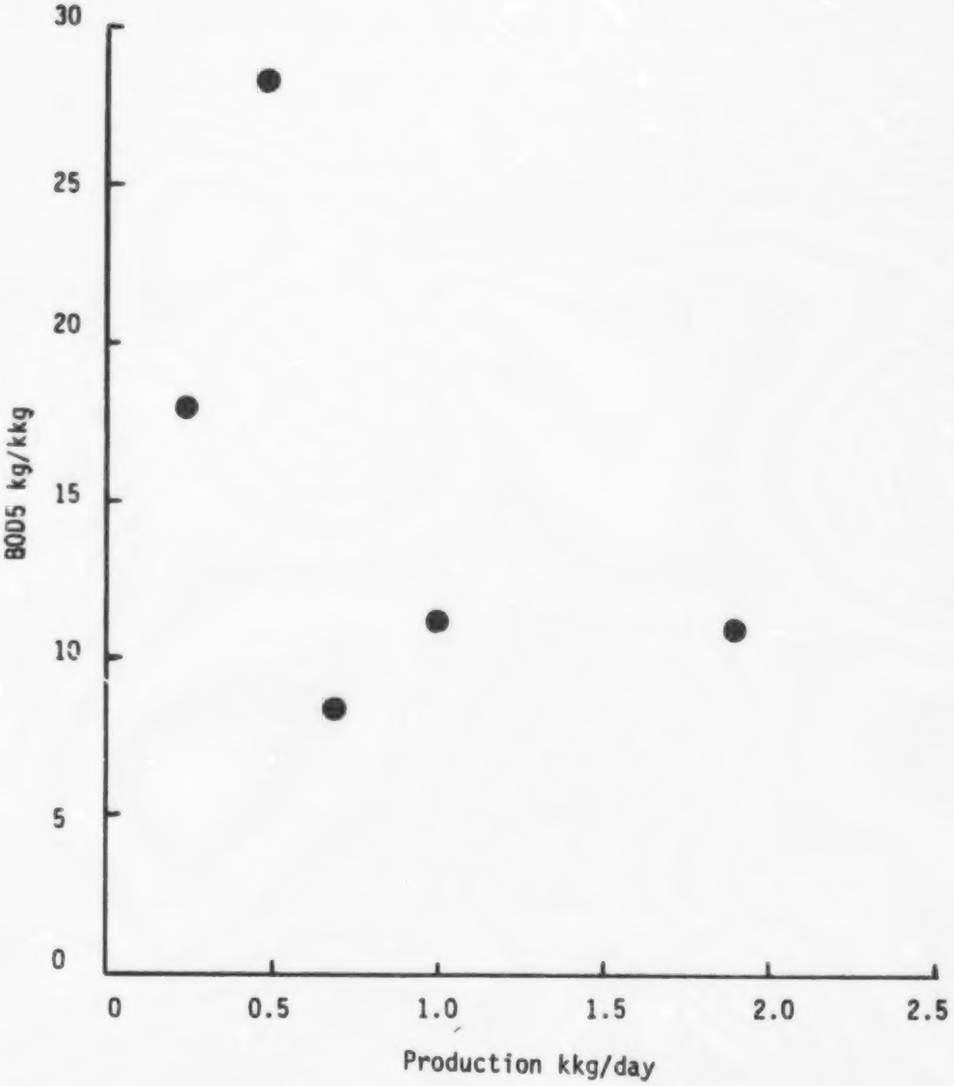


Figure 63
East Coast oyster BOD5 ratios
versus production level

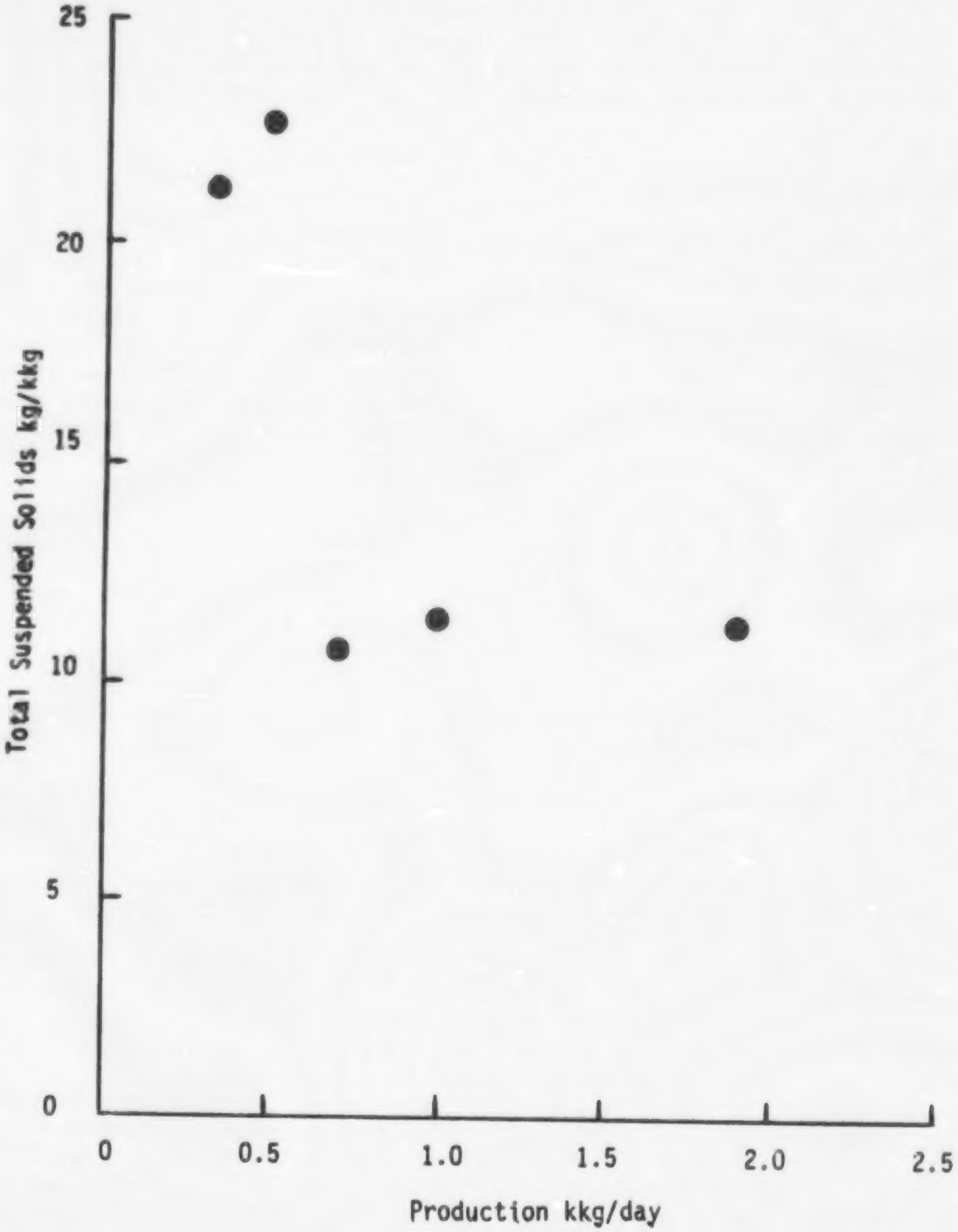


Figure 64
East Coast oyster total suspended solids ratios versus production level

The processing of scallops was considered to be less important than clam and oyster processing, since the waste loads were lower and fewer plants were in operation. A total of three Alaskan scallop processing operations were investigated and 13 unit operation and end-of-pipe composite samples of wastewater collected. The processing methods used for bay, sea and Alaskan scallops are similar. The calico scallop is processed in a different manner from the others; unfortunately, the 1973 harvest of calico scallops was very poor and no operations were observed.

## Process Description

The bay, sea and Alaskan scallops are processed for the fresh or frozen market. The scallops are hand-shucked at sea to avoid deterioration and the meat is iced and brought to the plant in bags. Figure 65 shows the flow diagram for a typical scallop process. After receiving the bagged scallops, the processors re-ice and ship them to other processors or freeze them immediately. In the plants investigated the scallops were either frozen in a package or individually quick frozen (IQF). The former involved a prewash in a five to seven percent salt brine. In plants using a fresh-water wash, a continuous flow was observed. The brine tank wash is merely a holding tank with no flow, except for make-up water and a complete recharge of the tank every eight hours or so. From the wash tank, the scallop meats are belted to inspection belts where debris and extraneous material are removed. After inspection, the scallops are put into plastic bags, weighed, boxed, and frozen in plate freezers. After freezing, the boxes are placed into cartons and held for shipment. The IQF process is identical except that after washing, the scallop meats are placed on a stainless steel mesh belt and conveyed into a blast freezer tunnel. After rapid freezing, the scallops are packaged and weighed, then packed in cartons for storage. In some plants, the larger scallops are first cut into smaller pieces before being frozen. A small percentage of the scallops is processed for the fresh market, but the vast majority is frozen in one form or another.

The calico scallop production began to become significant in about 1967, with the development of patented machinery which shucks and eviscerates the scallops automatically. In the past, the machinery was sometimes installed on the dredging vessel and the shucking operation done at sea; however, the processes are now all land based. The typical unit operations used are as follows (16). The scallops are piled on the dredge and unloaded via conveyor belt to the plant. The live scallops are separated from the loose shells by a shucker and conveyed through a heating tunnel. The heat opens the scallop and loosens the adductor muscle and visceral mass from the shell. The meat is then separated from the shell using a shucker and brine flotation. The meat then passes through a grinder-roller which removes remaining viscera and is then washed, sorted, and packed. The

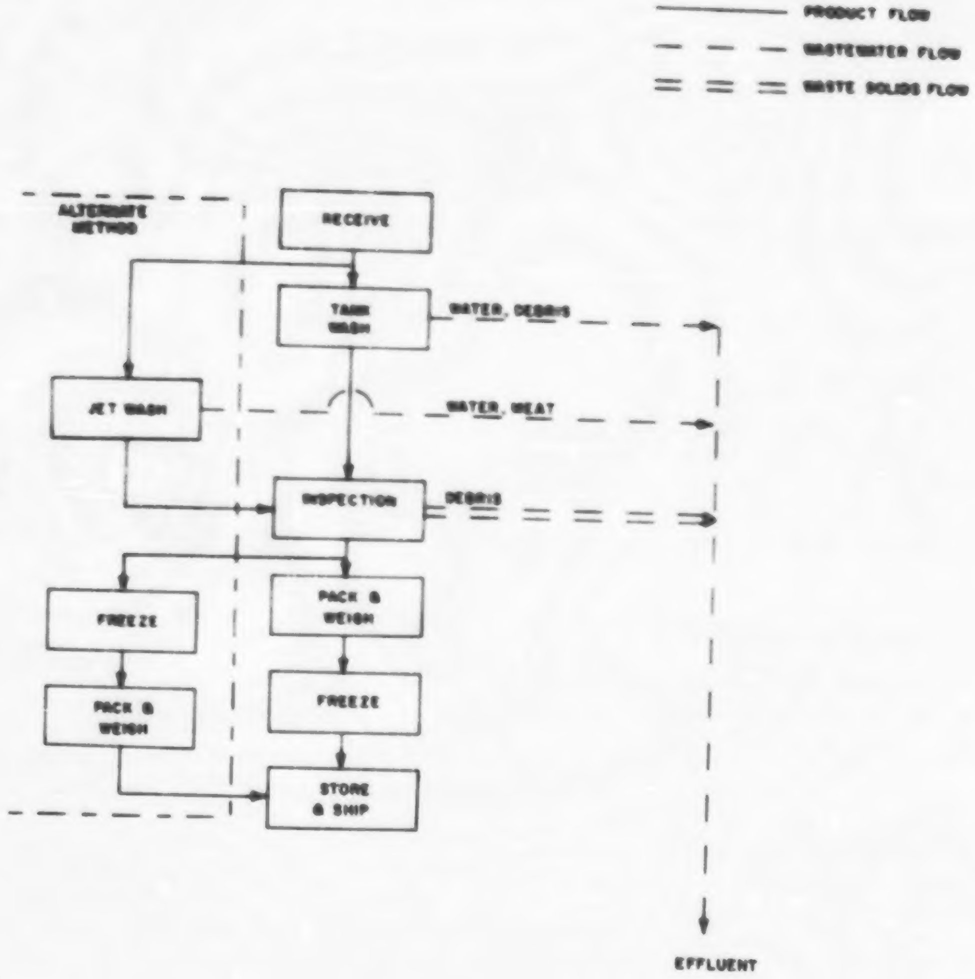

PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
ALTERNATE METHOD
RECEIVE
TANK WASH
WATER, DEBRIS
JET WASH
WATER, MEAT
INSPECTION
DEBRIS
FREEZE
PACK & WEIGH
PACK & WEIGH
FREEZE
STORE & SHIP
EFFLUENT

Figure 65. Typical scallop process.

yield is quite variable, with the average being about eight lbs of meat from two bushels of shell stock.

### Subcategorization Rationale

The only factor which was considered to influence subcategorization of the scallop industry (excluding calico scallops) was geographic location, since the processing operations are essentially the same. It was determined that the processing operations in Alaska be separated from those outside of Alaska because of the greater costs. Figure 66 shows a summary plot of the wastewater characteristics of two scallop processes in Alaska. It was noted that the flows and waste loads were minimal. Table 39 shows the average values of the wastewater parameters for the two plants. There are no data for non-Alaska operations, since the two Alaska plants were the only ones sampled. Other plants were observed in the Middle Atlantic region using essentially the same process; therefore, it should be a good assumption that the waste loads would be similar.

## ABALONE

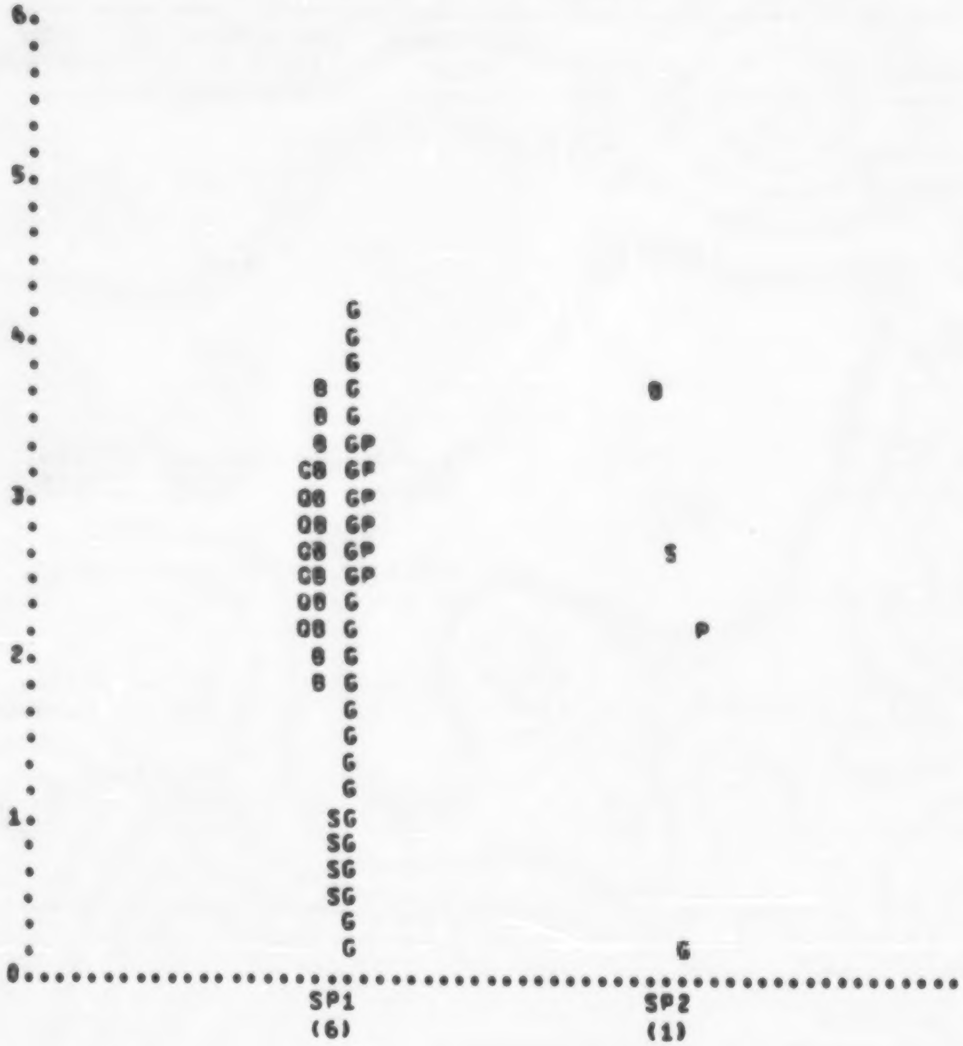
The processing of abalone was considered to be relatively unimportant from a wastewater control viewpoint, since the flows and waste loads are small and because there are relatively few plants. A total of three plants were investigated and 19 unit operation and end-of-pipe wastewater samples collected.

### Process Description

Figure 67 shows the flow diagram for a typical abalone process. The abalone are received at the plants in lots segregated according to species and the diver who harvested them. After unloading, the animal is removed from its shell with the aid of an iron bar known as a "punch out" bar. The visceral mass is separated from the large foot muscle which is then put into a washer. Several types of mechanical washers are in use, including a rotating drum type. The washwater is often recirculated and dumped at set time intervals. After washing, the mouth and head sections are cut away and the foot muscles are arranged on a large sorting table and allowed to rest. Before further processing can be accomplished the muscle must sit for an hour or more to relax. If the muscle is trimmed too soon after shucking, it still retains a degree of excitability and is difficult to handle.

Trimming follows the rest phase and is necessary to remove the pigmented epithial lining of the muscle prior to slicing. The mantel, the shell forming organ, is sliced off first, usually with a mechanical slicer of the type commonly used to slice meats. Next, the epidodium, the pad covering the bottom of the muscle, is sliced off with a mechanical slicer, and passed to a

Figure 66. **ALASKAN SCALLOP PROCESS PLOT.**



| SYMBOL | PARAMETER | SCALING FACTOR |
|---|---|---|
| Q | FLOW | 1 INCH = 5000 L/KKG |
| B | 5 DAY BOD | 1 INCH = 1 KG/KKG |
| S | SUSPENDED SOLIDS | 1 INCH = 0.5 KG/KKG |
| G | GREASE & OIL | 1 INCH = 0.1 KG/KKG |
| P | PRODUCTION | 1 INCH = 0.5 TON/HR |

## Table 39

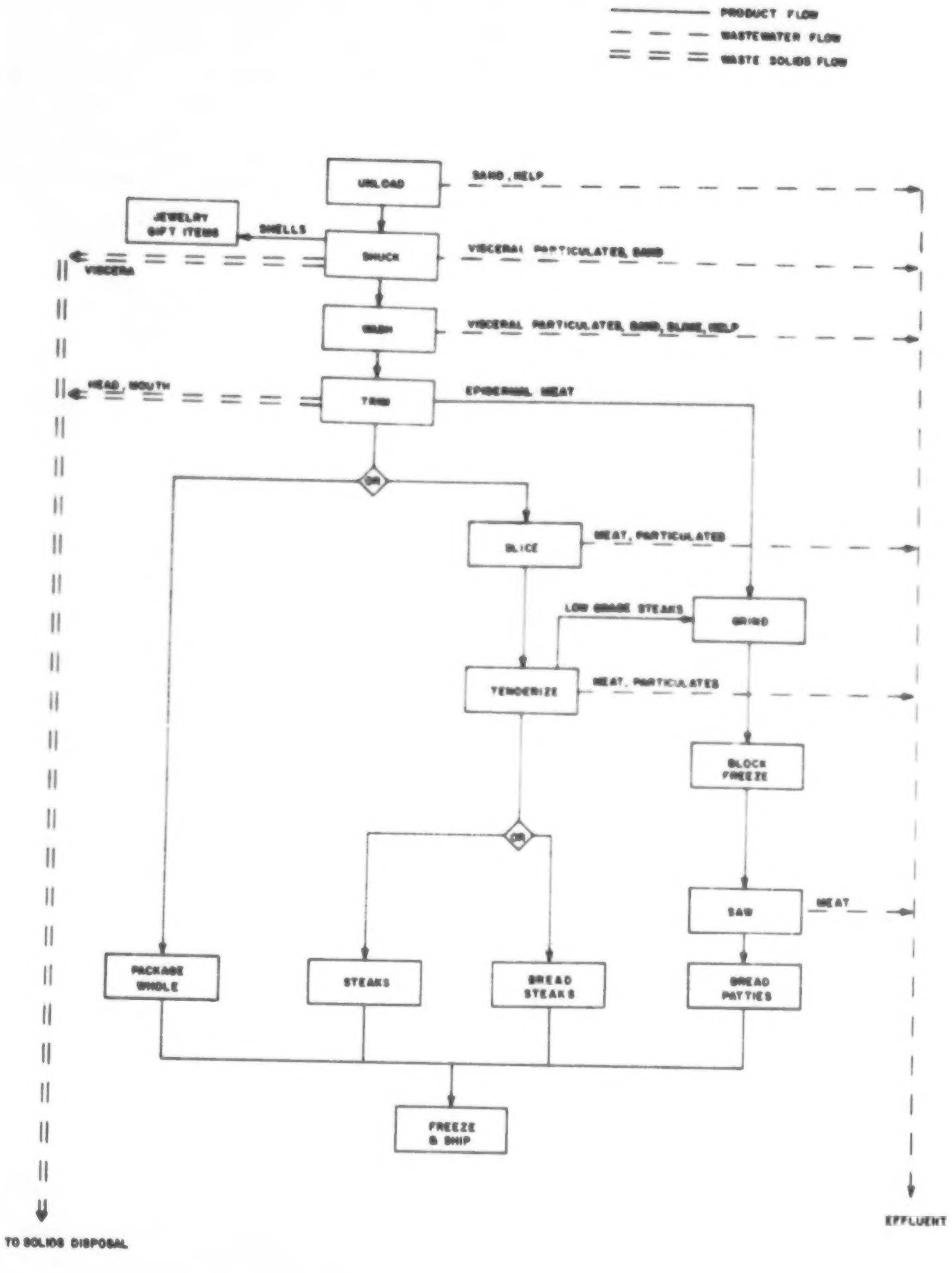
## SCALLOP
## PROCESS SUMMARY OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION* | | | | |
| (TON/HR) | 1.26 | | 0.304 | |
| TIME* | | | | |
| (HR/DAY) | 8.63 | | 4.05 | |
| FLOW* | | | | |
| (L/SEC) | 2.55 | | 3.48 | |
| (GAL/MIN) | 40.5 | | 55.2 | |
| FLOW RATIO** | | | | |
| (L/KKG) | 2150. | 7.672 | 2.615 | 951000. |
| (GAL/TON) | 515. | 6.243 | 2.615 | 228000. |
| TSS** | | | | |
| (MG/L) | 325. | 5.783 | 0.923 | 2790. |
| (KG/KKG) | 0.697 | -0.360 | 0.923 | 6.00 |
| BOD-5** | | | | |
| (MG/L) | 1460. | 7.286 | 0.200 | 2330. |
| (KG/KKG) | 3.13 | 1.142 | 0.200 | 5.00 |
| GREASE AND OIL** | | | | |
| (MG/L) | 20.1 | 3.003 | 2.221 | 3560. |
| (KG/KKG) | 0.043 | -3.140 | 2.221 | 7.64 |
| PH* | 6.66 | | | |

PLANTS SP1 ,SP2

* THE OUTPUT FOR THESE PARAMETERS
ARE THE NORMAL (UNWEIGHTED) MEAN
AND STANDARD DEVIATION, RESPECTIVELY

** THE OUTPUT FOR THESE PARAMETERS
ARE THE LOG NORMAL (UNWEIGHTED) MEAN
AND STANDARD DEVIATION, RESPECTIVELY



PRODUCT FLOW
WASTEWATER FLOW
WASTE SOLIDS FLOW
UNLOAD
SAND, KELP
JEWELRY GIFT ITEMS
SHELLS
SHUCK
VISCERA
VISCERAL PARTICULATES, SAND
WASH
VISCERAL PARTICULATES, SAND, SLIME, KELP
HEAD, MOUTH
TRIM
EPIDERMAL MEAT
OR
SLICE
MEAT, PARTICULATES
LOW GRADE STEAKS
GRIND
TENDERIZE
MEAT, PARTICULATES
BLOCK FREEZE
OR
SAW
MEAT
PACKAGE WHOLE
STEAKS
BREAD STEAKS
BREAD PATTIES
FREEZE & SHIP
TO SOLIDS DISPOSAL
EFFLUENT

Figure 67 Typical abalone process.

number of workers who complete the trimming manually. This last step, known as "up-trimming," is necessary to remove the fascia, a dark pigmented lining of the muscle. The trimmings are collected to be canned or made into breaded abalone patties. The abalone is then sliced and tenderized by pounding. Although attempts have been made to automate the last step, no satisfactory substitute has been found to replace the job of manually pounding the steaks. The steaks are then packaged to be sold fresh or frozen. Some steaks are breaded prior to freezing.

### Subcategorization Rationale

Since the abalone process is a relatively small industry which is located in one geographical area, it was determined to constitute one subcategory. The abalone process plot of selected waste parameters is shown in Figure 68. The summary statistics for the three abalone processes sampled are shown in Table 40.

Figure 68. **ABALONE** Process Plot

```
6.
 .
 .
 .
 .
 .
5.
 .
 .
 .
 .
 .
4.
 .         B
 .         B
 .         B
 .         B
 .         BS            S
3.        QBS
 .        QBS
 .        QBS
 .        QBS          Q
 .        QBS
 .        QBS           B
2.        QBS
 .        QBS                        S
 .        QBS                      QBS
 .          SG            G        QBS
 .          SG                     QBS
 .           G                     QBSG
1.           G                     QB G
 .           G                     QB G
 .           G                        G
 .            P                       G
 .            P                        P
 .                         P
0.........................................................
          AB1          AB2          AB3
          (4)          (1)          (3)

  SYMBOL        PARAMETER                  SCALING FACTOR
 ---------------------------------------------------------
    Q         FLOW                     1 INCH = 20000 L/KKG
    B         5 DAY BOD                1 INCH =  10   KG/KKG
    S         SUSPENDED SOLIDS         1 INCH =   5   KG/KKG
    G         GREASE & OIL             1 INCH =   1   KG/KKG
    P         PRODUCTION               1 INCH =  0.2  TON/HR
 ---------------------------------------------------------
```

## Table 40

### ABALONE
### PROCESS SUMMARY OF SELECTED PARAMETERS

| PARAMETER | MEAN | LOG NORMAL MEAN | LOG NORMAL STD DEV | 99% MAXIMUM |
|---|---|---|---|---|
| PRODUCTION* | | | | |
| (TON/HR) | 0.062 | | 0.015 | |
| TIME* | | | | |
| (HR/DAY) | 3.25 | | 1.71 | |
| FLOW* | | | | |
| (L/SEC) | 0.542 | | 0.091 | |
| (GAL/MIN) | 8.59 | | 1.44 | |
| FLOW RATIO** | | | | |
| (L/KKG) | 39300. | 10.579 | 0.385 | 96300. |
| (GAL/TON) | 9410. | 9.150 | 0.385 | 23100. |
| TSS** | | | | |
| (MG/L) | 282. | 5.641 | 0.381 | 684. |
| (KG/KKG) | 11.1 | 2.404 | 0.381 | 26.9 |
| BOD-5** | | | | |
| (MG/L) | 490. | 6.195 | 0.431 | 1340. |
| (KG/KKG) | 19.3 | 2.958 | 0.431 | 52.6 |
| GREASE AND OIL** | | | | |
| (MG/L) | 28.3 | 3.343 | 0.291 | 55.8 |
| (KG/KKG) | 1.11 | 0.106 | 0.291 | 2.19 |
| PH* | 7.11 | | | |

PLANTS AB1 ,AB2 ,AB3

* THE OUTPUT FOR THESE PARAMETERS ARE THE NORMAL (UNWEIGHTED) MEAN AND STANDARD DEVIATION, RESPECTIVELY

** THE OUTPUT FOR THESE PARAMETERS ARE THE LOG NORMAL (UNWEIGHTED) MEAN AND STANDARD DEVIATION, RESPECTIVELY

# SECTION V

# WASTE CHARACTERIZATION

## INTRODUCTION

A major effort in the Seafood Effluent Limitations Study involved field investigation of the wastewater emanating from processing plants in each segment of the industry. This was necessary because the most recent previous study concluded that very little knowledge of the character and volume of canned and preserved seafood processing wastewater was available (24).

The industry was characterized as follows: first, a preliminary segmentation, as described in Section IV, was conducted and the relative importance of these segments estimated; second, a representative number of plants in each segment was sampled; and third, the results of the field work were analyzed and final subcategories established. The data from typical plants belonging to each subcategory were then averaged to obtain an estimate of the characteristics of that subcategory. These estimates are referred to as the typical raw waste loads.

This section presents the results of the data analysis which was performed on the wastewater information collected and used to help establish the subcategories as discussed in Section IV. The results are organized by commodity or process, in the same sequence as Section IV. A brief introduction to each type of process provides background information on when and where that segment of the industry was monitored, and special sampling techniques, if any, which were required. The water and product material balances are discussed to indicate the sources of wastewater and the disposition of raw product to food and by-product and waste for typical operations. The raw waste loadings are discussed with special emphasis on major sources of water, BOD, and suspended solid within the plant as well as end-of-pipe.

### Sampling Procedures

Based on previous experience in examining wastes from the seafood processing industries, the parameters considered to be most important from the standpoint of waste control and treatment and which could be obtained within the alloted time and economic constraints were: flow, settleable solids, screened solids, suspended solids, 5-day BOD, COD, grease and oil, organic nitrogen, ammonia, pH, raw product input rate, and food and by-product recovery.

The field crews were instructed to increase the sampling frequency at point sources where the variation of the waste load appeared to be greater. Estimates of the daily fluctuations in the process were used to determine the duration of the sampling program at the plant. An attempt was made to increase the duration at plants which showed higher variability from day to day in order to obtain estimates with similar confidence intervals.

Depending on the effluent discharge system, plant sampling was accomplished several ways. For plants with a single point source, a time flow-proportioned composite sample was taken over the processing period each day by proportioning according to the previous flows. In cases where the effluent was discharged from more than one point source, the individual discharge flows were spatially composited on a flow proportioned basis to yield a total-effluent sample. These total-effluent samples were then time composited over the processing period. Some situations were difficult to composite, such as, when two or more unit operations made up a process, and were carried on at different times of a processing day. These point sources were then sampled separately and combined mathematically. The objective in all cases was to make the final composite sample representative of the total wastewater effluent discharged from the plant for that day of production.

Since flow-proportioning was a vital step in the sampling process, measurement of effluent flow rates were critical to the representativeness of the samples. Several methods of flow measurement were used by the field crews and are discussed in Section VI. Also, since flow rates together with production rates were the foundation upon which the waste load calculations are based, several flow measuring techniques were often used in conjunction to check accuracy. Production rates were determined from the total volume of raw product processed during the day and the length of the processing interval. After determination of the flow rates, the effluent samples were taken. Every attempt was made to obtain a well mixed representative sample of the effluent being discharged at the time of sampling. The correct volume of effluent was taken from the effluent stream at or near the point of discharge and the temperature measured immediately. The sample was then added to the sampling container, which was stored in a cool place throughout the day at the plant.

After preliminary field analyses for settleable solids and pH, four one-liter samples were prepared as follows: one sample was acidified to a pH of less than 2.0 and held at 4°C (40°F), one sample was preserved with 440 ppm of mercuric chloride and held at 4°C (40°F), and two samples were frozen with no chemical additions. When sufficient samples were obtained to make a shipment, the two chemically preserved refrigerated samples, one of the frozen samples, and the plastic bag containing the solids from the screen from each composite sample taken, were packed in styrofoam shipping cartons and air-freighted to an analytical laboratory in Portland, Oregon where the remainder of the parameters were measured. The second frozen sample was retained in storage locally for use in case of a lost shipment. Section

VI of this report explains in more detail how the wastewater parameters were measured and the precisions involved.

Data Reduction

Several computer programs, which proved to be very efficient tools for analyzing and presenting characterization data, were developed.

The first program, designated PLANTAVE, was used to calculate arithmetic estimates of time averages, standard deviation, and observed minimums and maximums of wastewater parameters from individual plants. The input is arranged by the datec the samples were collected and the points where the samples were collected. Sample points were grouped together if they were considered to be correlated, and grouped separately if uncorrelated. The data from sample points which were considered to be correlated were composited by adding the waste loads from each point for each day to obtain daily estimates of the total load from these points. The data must be present from each sample point on the same days in order to perform a correlated calculation. The waste load for sample points where data was collected infrequently (such as washdown) was considered to be independent of waste load from other points. The average load from each of the independent points was computed over all days and then added to the daily average from the other points to determine the overall average. A plant code corresponding to the type of process and the name of the plant from where the samples were taken was assigned to the output from the program to prevent data from being related to a particular plant.

An option to the PLANTAVE program was UNITOP. The UNITOP option calculated the loads from each sample point together with the percent that the point contributed to the total effluent. This information was used to develop the wastewater material balance tables presented in this section and was very useful in helping to determine where in-plant controls would be the most effective.

The next program, designated PROSPLOT, was used to plot arithmetic averages and standard deviations for five selected parameters for up to 17 processing operations. This allowed the data from selected plants to be visually integrated to help determine if they were similar enough to include in one subcategory. The codes for each of the plants plotted and the number of samples used to develop the information are shown on the horizontal axis below their respective characterization data. The five parameters plotted are: flow, BOD, suspended solids, grease and oil, and the production rate. The vertical scale is in inches with the scaling factor given at the bottom of the plot for each parameter. This plot allows the relative values of the plant parameters to be easily compared. The mean of each parameter is at the center of the vertical spread. The vertical spread represents one standard deviation above and below the mean, hence, the wider the vertical spread the more variable the data. These plots were used in Section IV to help determine how the industry should be subcategorized and which plants should be used to compute the average raw waste loads for each subcategory.

Once a decision was made on subcategorization, the data from the selected plants in the subcategory were used by the next program to compute and tabularize estimates of spatial averages (average of the plant means) utilizing a log-normal transform, log-normal means, log-normal standard deviations, and maximums for each selected summary parameter. The plants used to determine each spatial average are indicated by a code list at the bottom of the table.

## FISH MEAL PROCESS WASTEWATER CHARACTERISTICS

The wastewater characterization data from the fish meal production industry is organized into those facilities with solubles plants and those without solubles plants, because of the different sampling techniques and waste loads involved.

### Fish Meal Production with Solubles Plant

Five fish meal processes with solubles plants were sampled on the East, Gulf, and California Coasts. In addition, historical data taken in 1972 was available from two plants in the mid-Atlantic region (25). The field crews sampled the East Coast plants during August and September of 1973 which was near, or at the period of peak production. The 1972 data was taken during November which was past the period of peak production. The data from the Gulf and California was collected during October of 1973 when catches were intermittent and production was lower than normal.

Since the solubles plant produces the majority of the wastewater discharge, the sampling was centered around this aspect of the plant's operation. As described in Section IV, the stickwater, washwater, and bailwater generated in the pressing and drying operations are held in storage tanks to await processing by the solubles plant. As a result, the solubles plant operates out of time phase with the rest of the plant. Figure 69 presents a typical time sequence of activities showing periods during which fish were being pressed and dried, periods of corresponding solubles plant operation and the periods during which samples were taken by the field crew at a plant in the mid-Atlantic. The vertical axis presents activity (meal production, solubles plant operation, or sampling) in an on-off fashion, without showing the magnitudes. The figure shows that the pressing and drying operations for meal at this plant took place during the first six to 12 hours of a 24 hour period, with the solubles plant operation extending over 30 to 40 hour periods, depending on the volume of fish processed and the capacity of the solubles plant. Sampling

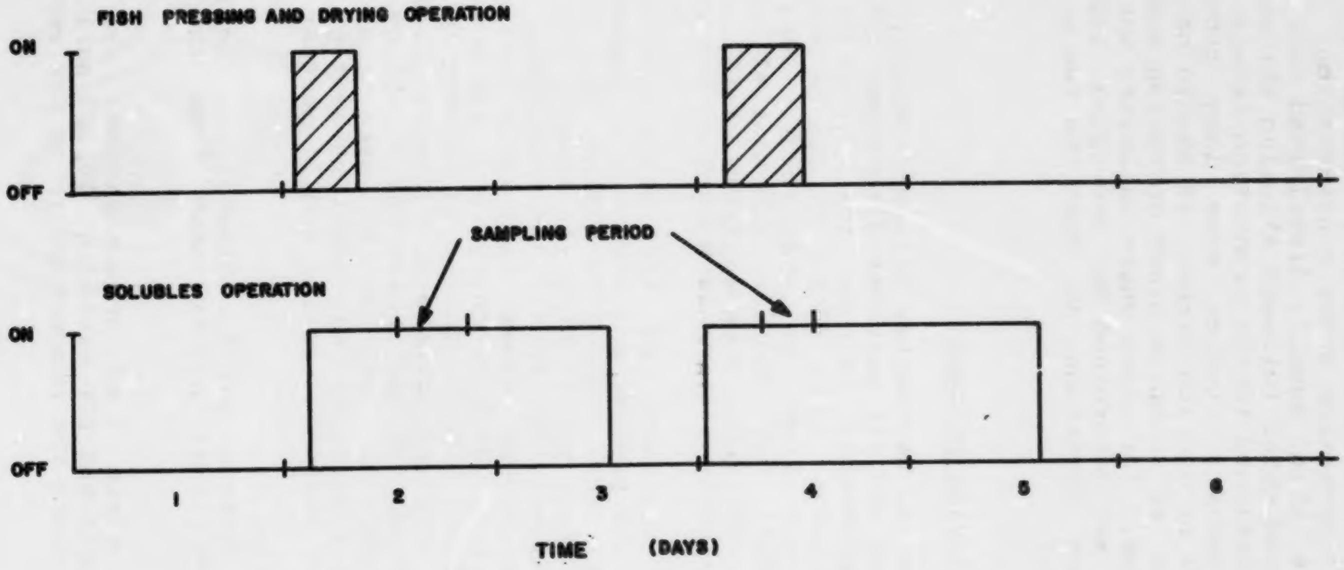


Figure 69. Fish meal process time sequence of activities.

occurred at various times during solubles plant operation. The basic assumption made was that the bailwater, washwater, and stickwater processed by the solubles plant during a given period resulted from the volume of fish processed just previous to the solubles plant operation under consideration. The amount of fish processed was then equally distributed over the solubles plant operation period which followed allowing the waste loads to be properly proportioned to the production levels. As a result, the wastewater summary tables show long processing times and relatively low production rates. It should be noted that these are in terms of solubles plant operation and not fish pressing and drying time. For cases where bailwater was being discharged, the flow rate was determined by averaging over the period of solubles plant operation so that the two waste loads could be added properly.

### Wastewater material balance

Table 41 shows the wastewater balance summary for plants with only evaporator and air scrubber discharges (M3, A2) and Table 42 shows the wastewater balance for plants with evaporator and bailwater discharges (M2H, M3H). It can be seen that the largest flows by far are from the evaporator. Bailwater flows are relatively small but contain substantial waste loads. Air scrubbers can contribute a relatively large flow and contain about the same concentration of wastes as the evaporators.

To determine how much of the waste load from the evaporator originates in the process and how much is caused by poor quality surface water, the evaporator intake, as well as the discharge was sampled at four plants with the results plotted on Figure 70. The plant codes with the suffix "I" correspond to data from the intakes. The figure shows that while most of the BOD load is caused by the evaporator process, very little suspended solids or grease and oil was added. Tables 43 through 46 contain the plant temporal data utilized for the subcategory summary. By examining the plant averages for the intake and discharge water of plants M2, M3, M5 and A2, it can be determined that the intake contributes an average of only eight percent of the BOD, but 52 percent of the suspended solids and 78 percent of the grease and oil

The waste levels from plants discharging bailwater are about three to five times higher than from those evaporating the bailwater.

The bailwater waste load concentrations are very high with suspended solids and BOD exceeding 20,000 mg/l. The waste loads are also high since the production rates are very high at fish meal plants.

### Product material balance

Table 41. Fish meal production with solubles plant material balance

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) evaporator | 80 - 85% | 60 - 85% | 60 - 90% |
| b) air scrubber | 15 - 20% | 15 - 40% | 10 - 40% |
| Total effluent average<br>M3, A2 | 51,000 l/kkg | 3.7 kg/kkg | 1.6 kg/kkg |

Product Material Balance Summary

| End Products | % of Raw Product |
|---|---|
| Products | |
| a) oil | 6 - 8% |
| b) meal | 20 - 21% |
| By-products | |
| a) solubles | 15% |
| Wastes | |
| a) water | 56 - 59% |

Average Production Rate, 540 kkg/day (600 tons/day)

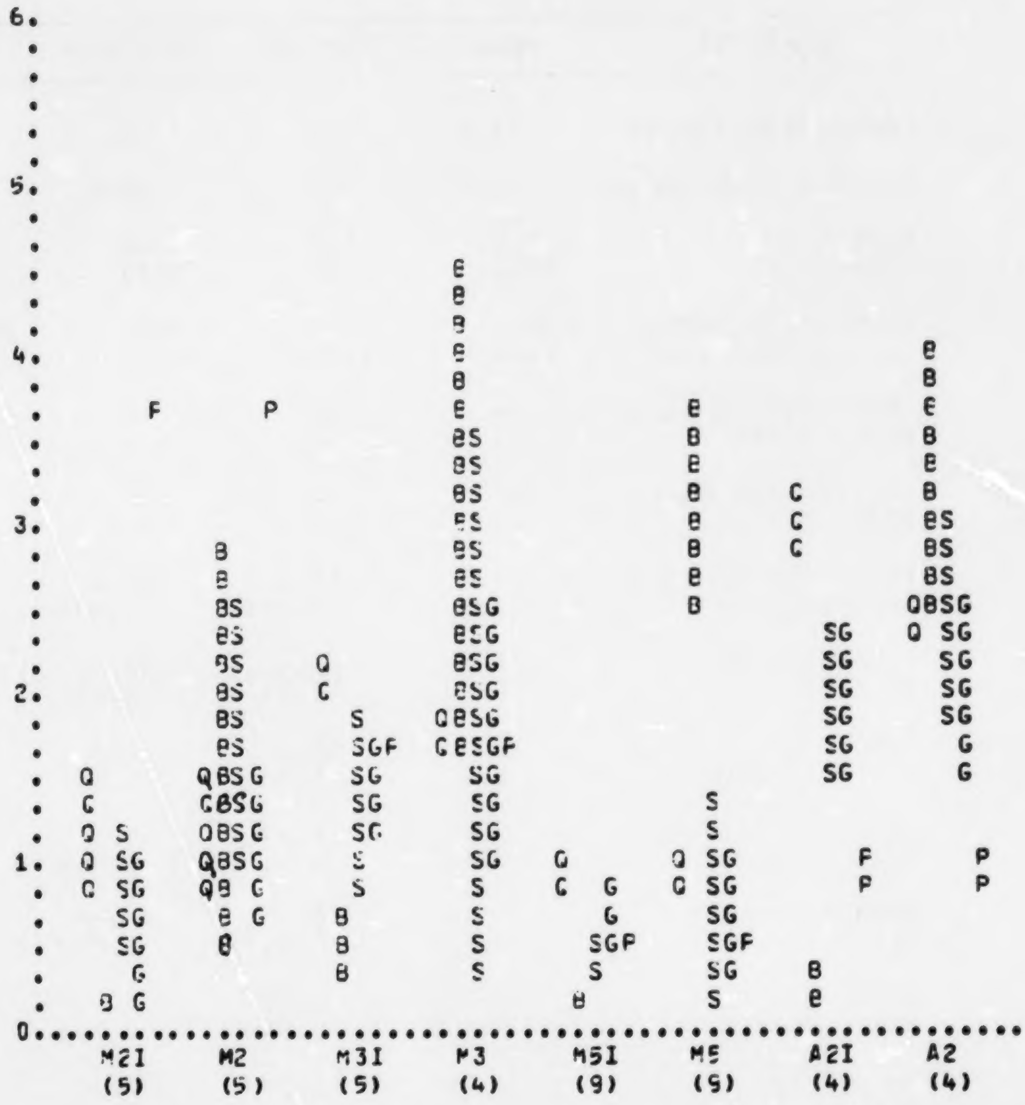
Table 42. Fish meal production with bailwater material balance

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) evaporator | >99% | 17 - 48% | 12 - 36% |
| b) bailwater | <1% | 52 - 83% | 64 - 88% |
| Total effluent average M2H, M3H | 29,300 l/kkg | 8 kg/kkg | 5 kg/kkg |

Average Production Rate, 450 kkg/day (495 tons/day)

Figure 70 Fish Meal Process Plant (with solubles plant) Intake and Discharge



| SYMBOL | PARAMETER | SCALING FACTOR |
|---|---|---|
| Q | FLOW | 1 INCH = 20000 L/KKG |
| B | 5 DAY BOD | 1 INCH = 1 KG/KKG |
| S | SUSPENDED SOLIDS | 1 INCH = 0.5 KG/KKG |
| G | GREASE & OIL | 1 INCH = 0.5 KG/KKG |
| P | PRODUCTION | 1 INCH = 20 TON/HR |

## Table 43. MENHADEN REDUCTION PROCESS (DISCHARGE)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 73.3 | -- | -- | -- |
| PROCESS TIME HR/DAY | 22.2 | -- | 20.0 | 24.0 |
| FLOW L/SEC | 415 | 131 | 235 | 559 |
| (GAL/MIN) | 6600 | 2080 | 3730 | 8870 |
| FLOW RATIO L/KKG | 22500 | 7110 | 12800 | 30300 |
| (GAL/TON) | 5400 | 1700 | 3060 | 7260 |
| SETT. SOLIDS ML/L | -- | -- | -- | -- |
| RATIO L/KKG | -- | -- | -- | -- |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 39.0 | 17.3 | 23.8 | 60.5 |
| RATIO KG/KKG | 0.879 | 0.389 | 0.536 | 1.36 |
| 5 DAY BOD MG/L | 75.3 | 49.9 | 27.7 | 138 |
| RATIO KG/KKG | 1.70 | 1.12 | 0.625 | 3.10 |
| COD MG/L | 147 | 59.2 | 84.1 | 210 |
| RATIO KG/KKG | 3.30 | 1.33 | 1.89 | 4.72 |
| GREASE & OIL MG/L | 23.6 | 9.33 | 14.9 | 35.0 |
| RATIO KG/KKG | 0.532 | 0.210 | 0.336 | 0.787 |
| ORGANIC-N MG/L | 5.46 | 2.55 | 3.20 | 8.47 |
| RATIO KG/KKG | 0.123 | 0.057 | 0.072 | 0.191 |
| AMMONIA-N MG/L | 8.36 | 3.90 | 4.17 | 13.9 |
| RATIO KG/KKG | 0.188 | 0.088 | 0.094 | 0.313 |
| PH | 7.75 | 0.320 | 7.30 | 8.75 |
| TEMP DEG C | 42.6 | 1.45 | 41.1 | 44.4 |

PLANT M2
5 SAMPLES

### Table 44. MENHADEN REDUCTION PROCESS
### (DISCHARGE)
### (NO SCRUBBER WATER)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 32.0 | -- | -- | -- |
| PROCESS TIME HR/DAY | 23.2 | -- | -- | -- |
| FLOW L/SEC | 282 | 4.02 | 278 | 287 |
| (GAL/MIN) | 4470 | 63.9 | 4420 | 4560 |
| FLOW RATIO L/KKG | 35000 | 500 | 34600 | 35700 |
| (GAL/TON) | 8390 | 120 | 8300 | 8560 |
| SETT. SOLIDS ML/L | -- | -- | -- | -- |
| RATIO L/KKG | -- | -- | -- | -- |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 28.0 | 22.7 | 15.9 | 62.0 |
| RATIO KG/KKG | 0.981 | 0.794 | 0.555 | 2.17 |
| 5 DAY BOD MG/L | 88.1 | 41.8 | 26.8 | 121 |
| RATIO KG/KKG | 3.09 | 1.46 | 0.937 | 4.22 |
| COD MG/L | 196 | 83.9 | 86.7 | 286 |
| RATIO KG/KKG | 6.86 | 2.94 | 3.04 | 10.0 |
| GREASE & OIL MG/L | 25.0 | 10.4 | 13.8 | 39.0 |
| RATIO KG/KKG | 0.876 | 0.366 | 0.485 | 1.37 |
| ORGANIC-N MG/L | 4.20 | 3.74 | 2.24 | 9.80 |
| RATIO KG/KKG | 0.147 | 0.131 | 0.079 | 0.343 |
| AMMONIA-N MG/L | 2.32 | 0.803 | 1.78 | 3.50 |
| RATIO KG/KKG | 0.081 | 0.028 | 0.062 | 0.123 |
| PH | 6.20 | 0.228 | 5.90 | 6.60 |
| TEMP DEG C | 39.7 | 0.321 | 39.4 | 40.0 |

PLANT M3
4 SAMPLES

## Table 45 . MENHADEN REDUCTION PROCESS (DISCHARGE)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 9.23 | 0.044 | 9.15 | 9.26 |
| PROCESS TIME HR/DAY | 18.3 | -- | 14.0 | 24.0 |
| FLOW L/SEC | 40.3 | 4.84 | 36.1 | 50.1 |
| (GAL/MIN) | 640 | 76.8 | 573 | 796 |
| FLOW RATIO L/KKG | 17400 | 2040 | 15600 | 21500 |
| (GAL/TON) | 4160 | 489 | 3730 | 5150 |
| SETT. SOLIDS ML/L | 8.18 | 19.5 | 0.276 | 56.3 |
| RATIO L/KKG | 142 | 338 | 4.78 | 978 |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 22.0 | 17.5 | 11.9 | 67.9 |
| RATIO KG/KKG | 0.382 | 0.304 | 0.207 | 1.18 |
| 5 DAY BOD MG/L | 178 | 31.1 | 126 | 219 |
| RATIO KG/KKG | 3.08 | 0.540 | 2.18 | 3.81 |
| COD MG/L | 303 | 56.6 | 205 | 385 |
| RATIO KG/KKG | 5.26 | 0.982 | 3.56 | 6.69 |
| GREASE & OIL MG/L | 19.8 | 8.54 | 12.6 | 39.5 |
| RATIO KG/KKG | 0.343 | 0.148 | 0.218 | 0.686 |
| ORGANIC-N MG/L | 2.99 | 2.73 | 1.26 | 9.53 |
| RATIO KG/KKG | 0.052 | 0.047 | 0.022 | 0.165 |
| AMMONIA-N MG/L | 1.33 | 0.582 | 0.415 | 2.53 |
| RATIO KG/KKG | 0.023 | 0.010 | 0.007 | 0.044 |
| PH | 4.33 | 0.181 | 4.11 | 9.93 |
| TEMP DEG C | 47.0 | 2.49 | 43.3 | 51.1 |

PLANT M5
9 SAMPLES

## Table 4b. ANCHOVY REDUCTION PROCESS
## (DISCHARGE)
## (WITHOUT SCRUBBER)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 19.0 | 1.13 | 17.5 | 20.0 |
| PROCESS TIME HR/DAY | 24.0 | — | — | — |
| FLOW L/SEC | 231 | 5.48 | 225 | 238 |
| (GAL/MIN) | 3670 | 87.1 | 3570 | 3790 |
| FLOW RATIO L/KKG | 48400 | 603 | 47700 | 49200 |
| (GAL/TON) | 11600 | 145 | 11400 | 11800 |
| SETT. SOLIDS ML/L | — | — | — | — |
| RATIO L/KKG | — | — | — | — |
| SCR. SOLIDS MG/L | — | — | — | — |
| RATIO KG/KKG | — | — | — | — |
| SUSP. SOLIDS MG/L | 25.1 | 5.99 | 16.4 | 30.7 |
| RATIO KG/KKG | 1.22 | 0.290 | 0.795 | 1.49 |
| 5 DAY BOD MG/L | 67.4 | 15.1 | 44.7 | 89.2 |
| RATIO KG/KKG | 3.26 | 0.730 | 2.16 | 4.32 |
| COD MG/L | 185 | 31.0 | 144 | 229 |
| RATIO KG/KKG | 8.93 | 1.50 | 6.98 | 11.1 |
| GREASE & OIL MG/L | 21.1 | 5.16 | 15.5 | 27.8 |
| RATIO KG/KKG | 1.02 | 0.250 | 0.749 | 1.34 |
| ORGANIC-N MG/L | 5.76 | 1.11 | 4.84 | 7.33 |
| RATIO KG/KKG | 0.279 | 0.054 | 0.234 | 0.355 |
| AMMONIA-N MG/L | 0.982 | 0.112 | 0.807 | 1.13 |
| RATIO KG/KKG | 0.048 | 0.005 | 0.039 | 0.055 |
| PH | 6.00 | 0.353 | 5.60 | 6.68 |
| TEMP DEG C | 14.1 | 10.5 | 5.99 | 29.2 |

PLANT A2
4 SAMPLES

The end products of fish meal reduction are fish meal, oil, and fish solubles; fish solubles being a product of stickwater and bailwater evaporation. The product material balance portion of Table 41 shows the relative amounts of each product obtained in the process. Yields will vary somewhat according to the season, the species processed, and the efficiency of the plant. A significant portion of the water contained in the fish exits the plant as waste vapor in the meal drying process and in the evaporator process.

Plants M2, M2H, M3, M3H and M5 were processing menhaden exclusively during the sampling periods with production rates averaging about 640 kkg/day (700 tons/day). Plant M1 was processing mostly menhaden along with some scraps from bottom fish and herring plants and had an average production rate of about 200 kkg/day (220 tons/day). Plant A2 was processing anchovy exclusively during the sample period and had an average production rate of 410 kkg/day (460 tons/day).

## Fish Meal Production Without Solubles Plant

Two fish meal plants without solubles plants were sampled on the California Coast during October 1973. The sampling period was during the peak season, however, the weather and the fact that some fishing boats alternate between squid and anchovies, caused intermittent operation.

### Wastewater material balance

Table 47 shows the wastewater balance summary for a fish meal plant with no solubles plant discharging stickwater and bailwater. The largest and strongest flow is the stickwater which is the liquid remaining after the oil is recovered from the press liquor. The waste load from the stickwater is one of the strongest in the entire seafood industry being very high in BOD, suspended solids, and grease and oil. The bailwater is also a relatively high flow and load and has similar characteristics to the bailwater described previously for the menhaden processes.

Tables 48 and 49 show the discharge characteristics for the two plants sampled, A1 and A3 respectively. Plant A3 had an air scrubber which contributed about 15 percent of the flow but almost no waste load. Plant A1 used a once pass bailwater system which increased the flow substantially, compared to A3 which unloaded the fish using a high pressure hose from a truck.

### Product material balance

Table 47 shows the disposition of the raw product for plants discharging stickwater. There is more waste from these plants because the solubles are not recovered.

Table 47. Fish meal production without solubles plant material balance

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) stickwater | 45% | 93% | 94% |
| b) bailwater | 39% | 7% | 6% |
| c) washdown | 1% | <1% | <1% |
| d) air scrubber | 15% | <1% | <1% |
| Total effluent average<br>A3 | 1870 l/kkg | 71 kg/kkg | 59 kg/kkg |

Product Material Balance Summary

| End Products | % of Raw Product |
|---|---|
| Products | |
| a) meal | 28% |
| b) oil | 8% |
| Wastes | |
| a) stickwater | 35% |
| b) water vapor | 29% |

Average Production Rate, 187 kkg/day (207 tons/day)

## Table 48. ANCHOVY REDUCTION PROCESS (DISCHARGE)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 6.57 | 0.910 | 5.53 | 7.15 |
| PROCESS TIME HR/DAY | 7.33 | -- | 3.80 | 11.0 |
| FLOW L/SEC | 22.2 | 12.5 | 9.39 | 34.4 |
| (GAL/MIN) | 352 | 199 | 149 | 547 |
| FLOW RATIO L/KKG | 12900 | 6190 | 6750 | 19100 |
| (GAL/TON) | 3090 | 1480 | 1620 | 4590 |
| SETT. SOLIDS ML/L | 1.71 | 0.473 | 1.29 | 2.22 |
| RATIO L/KKG | 22.1 | 6.10 | 16.7 | 28.7 |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 1790 | 935 | 1180 | 2860 |
| RATIO KG/KKG | 23.1 | 12.1 | 15.2 | 36.9 |
| 5 DAY BOD MG/L | 3600 | 1790 | 2070 | 5570 |
| RATIO KG/KKG | 46.4 | 23.1 | 26.7 | 71.8 |
| COD MG/L | 6160 | 2970 | 3790 | 9490 |
| RATIO KG/KKG | 79.5 | 38.3 | 48.9 | 122 |
| GREASE & OIL MG/L | 968 | 1020 | 94.9 | 2090 |
| RATIO KG/KKG | 12.5 | 13.1 | 1.22 | 26.9 |
| ORGANIC-N MG/L | 399 | 171 | 265 | 591 |
| RATIO KG/KKG | 5.15 | 2.20 | 3.42 | 7.63 |
| AMMONIA-N MG/L | 19.9 | 13.2 | 11.0 | 35.1 |
| RATIO KG/KKG | 0.257 | 0.171 | 0.142 | 0.453 |
| PH | 6.82 | 0.192 | 6.63 | 7.18 |
| TEMP DEG C | 21.3 | 4.02 | 16.7 | 23.9 |

PLANT A1
3 SAMPLES

## Table 49. ANCHOVY REDUCTION PROCESS (WITH AIR SCRUBBER WATER)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 8.63 | 0.411 | 8.33 | 9.08 |
| PROCESS TIME HR/DAY | 24.0 | -- | -- | -- |
| FLOW L/SEC | 4.00 | 0.234 | 3.72 | 4.52 |
| (GAL/MIN) | 63.5 | 3.71 | 59.1 | 71.7 |
| FLOW RATIO L/KKG | 1870 | 114 | 1770 | 2120 |
| (GAL/TON) | 448 | 27.3 | 425 | 509 |
| SETT. SOLIDS ML/L | 221 | 51.3 | 167 | 305 |
| RATIO L/KKG | 412 | 95.8 | 313 | 570 |
| SCR. SOLIDS MG/L | 246 | -- | -- | -- |
| RATIO KG/KKG | 0.459 | -- | -- | -- |
| SUSP. SOLIDS MG/L | 31400 | 18100 | 11500 | 60800 |
| RATIO KG/KKG | 58.6 | 33.7 | 21.5 | 114 |
| 5 DAY BOD MG/L | 37900 | 11000 | 22500 | 49300 |
| RATIO KG/KKG | 70.8 | 20.6 | 42.0 | 92.1 |
| COD MG/L | 78200 | 38600 | 34200 | 138000 |
| RATIO KG/KKG | 146 | 72.1 | 63.8 | 258 |
| GREASE & OIL MG/L | 20100 | 13800 | 2730 | 39800 |
| RATIO KG/KKG | 37.5 | 25.7 | 5.11 | 74.3 |
| ORGANIC-N MG/L | 2810 | 1050 | 960 | 3420 |
| RATIO KG/KKG | 5.24 | 1.95 | 1.79 | 6.39 |
| AMMONIA-N MG/L | 99.7 | 33.2 | 45.1 | 136 |
| RATIO KG/KKG | 0.186 | 0.062 | 0.084 | 0.255 |
| PH | 6.78 | 0.060 | 6.68 | 6.87 |
| TEMP DEG C | 43.3 | 2.34 | 40.7 | 45.7 |

PLANT A3
5 SAMPLES

Both A1 and A3 were processing anchovy exclusively during the sampling period. Production rates ranged from 44 kkg/day (50 tons/day) at the smaller plant (A1) to 190 kkg/day (210 tons/day) at the larger plant.

## SALMON CANNING PROCESS WASTEWATER CHARACTERISTICS

Three salmon canning plants in Alaska and two plants in the Northwest were investigated during the period from July to August 1973. In addition historical data were obtained from four plants in the Northwest, including the two sampled.

The 1973 Alaska salmon season was very poor, therefore more fish were going to the fresh/frozen market and the canning operations were very intermittent. Most of the canneries are presently grinding their waste and discharging to a submarine outfall, therefore, end of pipe samples were relatively easy to obtain at a common sump.

The Northwest plants investigated were sampled during the end of September which was near the end of the season. The Northwest plants usually have both hand butchering and mechanical butchering lines, hence there was a combined operation during most of the investigation period. The butchering machine was usually operated only during times when large volumes of fish, usually pinks and chums, arrive at the plant. Silver and chinook salmon were usually hand butchered. Hand packing of sockeye was also done for special orders that required a finer quality product.

### Wastewater Material Balance

The intake water for Alaskan salmon plants located in isolated places is obtained from nearby surface water streams. The intake water for plants located in town is usually from the municipal systems. The water used in the canneries is chlorinated either by the plant or by the municipal treatment system. City water is generally used by Northwest plants for all phases of the operation.

Table 50 shows the wastewater balance for salmon canning operations using the butchering machine. It can be seen that this machine contributes a significant portion of the flow and a very great portion of the BOD and suspended solids load. The main reason that the BOD loads for the Northwest plants were quite variable, and generally lower than the Alaskan plants (see Figure 25), was because the butchering machines were used only on a portion of the total fish processed.

Table 51 shows the wastewater material balance for an exclusively hand butchering operation (CSN5, CS6M). It can be seen that the total loads are much lower for the hand butchering operation than

Table 50 Salmon canning process material balance (mechanized)

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) unloading water | 12% | 10% | 7% |
| b) iron chink | 27% | 65% | 56% |
| c) fish scrubber | 19% | 5% | 3% |
| d) sliming table | 13% | 6% | 18% |
| e) fish cutter | 7% | 4% | 5% |
| f) can washer and clincher | 2% | 1% | 1% |
| g) washdown | 20% | 10% | 11% |
| Total effluent average | 19800 l/kkg | 45.5 kg/kkg | 24.5 kg/kkg |

Product Material Balance Summary

| End Products | % of Raw Product |
|---|---|
| Food products | 62 - 68% |
| By-product | |
| a) roe | 4 - 6% |
| b) milt | 2 - 3% |
| c) oil | 1% |
| d) heads | 12 - 14% |
| e) viscera | 0 - 5% |
| Wastes | 11 - 16% |

Average Production Rate, 37 kkg/day (41 tons/day)

Table 51. Salmon canning process material balance (hand butcher).

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) butchering line | 20% | 24% | 17% |
| b) fish cutter | 20% | 16% | 17% |
| c) can filler | 5% | 21% | 30% |
| d) can washer | 22% | 5% | 5% |
| e) washdown | 33% | 34% | 30% |
| Total effluent Average<br>CSN5, CS6M | 5400 l/kkg | 3.4 kg/kkg | 2.0 kg/kkg |

Average Production Rate, 4.8 kkg/day (5.3 tons/day) for the mechanical butchering line. The hand butcher canning process is identical to the fresh/frozen operation except for the wastes from the fish cutting and can filling operation, which increase the load about 45 percent more. Plant CSN2 used a hand packing operation rather than a mechanical filler, therefore, their wastes were lower.

Tables 52 through 57 show summary statistics of the wastewater for the plants utilized in the subcategory summary. Figure 29 contains a normalized salmon canning process plot of selected wastewater parameters from each plant sampled. Codes CSN2, CSN3 and CSN4 represent Alaskan plants which used the butchering machine exclusively. Codes CSN5 through CSN8 represent Northwest plants which used the butchering machine in varying amounts. Code CSN5 used hand butchering exclusively, plant CS8H (historical data from CSN8) used the butchering machine exclusively, while the rest of the plants used it occasionally.

Plant CSN8 had a poor water conservation practice of letting water run through the butchering machine in between periods of operation. This practice caused the flow ratio to be much greater than normal at this plant. CSN8 also used a flume unloading system which was not observed at the other plants and which produced an added flow of about 4170 l/kkg (1000 gal/ton). The added waste load in terms of BOD, however, was very small.

Most of the plants in Alaska grind the larger solids before discharge to submerged outfalls. Some plants were beginning to install screens in 1973 but none were operational during the sampling interval.

Most plants in the Northwest discharge the wastewater after coarse screening to remove the larger particles. Plant CSN7 had a tangential screen in place and samples were taken to determine its effectiveness. The tangential screen removed the screenable solids effectively, however, the BOD and suspended solids were observed to increase slightly (it should be noted that the "before screening" samples were passed through a 20 mesh Tyler screen prior to analysis). The reason for this is believed to be due to the type of pump used to deliver the water to the screen. The pump could have pulverized some of the solid material causing the number of undersize particles to increase (see Section VII, Screening).

## Product Material Balance

Table 50 shows the product material balance which is similar for either hand or mechanical butchering. The food recovery varies with species and is a little greater for the hand butchering operation. Solid wastes such as the heads and viscera are usually discharged to the receiving water in Alaska and are usually recovered in the Northwest for pet food, mink food, or fish meal.

## Table 52. SALMON CANNING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 3.16 | 0.761 | 1.67 | 3.94 |
| PROCESS TIME HR/DAY | 6.00 | -- | 2.50 | 10.0 |
| FLOW L/SEC | 13.9 | 2.67 | 10.1 | 17.8 |
| (GAL/MIN) | 220 | 42.5 | 160 | 283 |
| FLOW RATIO L/KKG | 18300 | 3690 | 13600 | 25100 |
| (GAL/TON) | 4370 | 884 | 3270 | 6010 |
| SETT. SOLIDS ML/L | 2.97 | 1.26 | 1.68 | 4.81 |
| RATIO L/KKG | 54.3 | 22.9 | 30.7 | 87.8 |
| SCR. SOLIDS MG/L | 1390 | 573 | 824 | 2610 |
| RATIO KG/KKG | 25.4 | 10.5 | 15 | 47.7 |
| SUSP. SOLIDS MG/L | 726 | 252 | 448 | 1190 |
| RATIO KG/KKG | 13.2 | 4.61 | 8.17 | 21.6 |
| 5 DAY BOD MG/L | 1330 | 451 | 719 | 2100 |
| RATIO KG/KKG | 24.2 | 8.23 | 13.1 | 38.3 |
| COD MG/L | 2470 | 490 | 1670 | 3090 |
| RATIO KG/KKG | 45.1 | 8.95 | 30.4 | 56.4 |
| GREASE & OIL MG/L | 175 | 62.0 | 99.2 | 271 |
| RATIO KG/KKG | 3.19 | 1.13 | 1.81 | 4.95 |
| ORGANIC-N MG/L | 175 | 48.9 | 81.5 | 236 |
| RATIO KG/KKG | 3.20 | 0.892 | 1.49 | 4.30 |
| AMMONIA-N MG/L | 5.33 | 1.41 | 2.93 | 7.16 |
| RATIO KG/KKG | 0.097 | 0.026 | 0.053 | 0.131 |
| PH | 6.88 | 0.109 | 6.71 | 7.09 |
| TEMP DEG C | 11.9 | 0.554 | 11.3 | 12.6 |

PLANT CSN2
7 SAMPLES

## Table 53. SALMON CANNING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | P 4.62 | 0.548 | 4.06 | 5.32 |
| PROCESS TIME HR/DAY | 8.25 | -- | 4.00 | 12.0 |
| FLOW L/SEC | 22.0 | 3.38 | 17.8 | 26.5 |
| (GAL/MIN) | 349 | 53.6 | 283 | 421 |
| FLOW RATIO L/KKG | 19000 | 2470 | 15100 | 21300 |
| (GAL/TON) | 4560 | 592 | 3620 | 5100 |
| SETT. SOLIDS ML/L | 46.3 | 9.37 | 34.5 | 54.2 |
| RATIO L/KKG | 882 | 178 | 657 | 1030 |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 2140 | 1080 | 1020 | 3270 |
| RATIO KG/KKG | 40.8 | 20.6 | 19.5 | 62.2 |
| 5 DAY BOD MG/L | 4300 | 756 | 3470 | 5190 |
| RATIO KG/KKG | 81.8 | 14.4 | 66.0 | 98.8 |
| COD MG/L | 7510 | 1450 | 5460 | 8890 |
| RATIO KG/KKG | 143 | 27.6 | 104 | 169 |
| GREASE & OIL MG/L | 341 | 2.11 | 339 | 343 |
| RATIO KG/KKG | 6.49 | 0.040 | 6.46 | 6.53 |
| ORGANIC-N MG/L | 816 | 394 | 410 | 1260 |
| RATIO KG/KKG | 15.5 | 7.49 | 7.81 | 24.0 |
| AMMONIA-N MG/L | 16.7 | 6.26 | 7.97 | 22.3 |
| RATIO KG/KKG | 0.317 | 0.119 | 0.152 | 0.424 |
| PH | 6.82 | 0.080 | 6.73 | 6.96 |
| TEMP DEG C | 12.9 | 1.07 | 11.8 | 13.8 |

PLANT CSN3
4 SAMPLES

### Table 54 . SALMON CANNING PROCESS (WITH GRINDING)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 4.49 | 1.34 | 2.63 | 5.89 |
| PROCESS TIME HR/DAY | 7.13 | -- | 4.50 | 9.50 |
| FLOW L/SEC | 21.2 | 3.76 | 14.6 | 26.8 |
| (GAL/MIN) | 336 | 59.8 | 231 | 425 |
| FLOW RATIO L/KKG | 20400 | 8050 | 13200 | 31400 |
| (GAL/TON) | 4900 | 1930 | 3170 | 7520 |
| SETT. SOLIDS ML/L | 25.5 | 22.5 | 4.20 | 64.3 |
| RATIO L/KKG | 522 | 459 | 85.8 | 1320 |
| SCR. SOLIDS MG/L | 2360 | 2010 | 552 | 5580 |
| RATIO KG/KKG | 48.3 | 41.1 | 11.3 | 114 |
| SUSP. SOLIDS MG/L | 1460 | 384 | 857 | 1980 |
| RATIO KG/KKG | 29.8 | 7.86 | 17.5 | 40.4 |
| 5 DAY BOD MG/L | 2610 | 1170 | 1400 | 4670 |
| RATIO KG/KKG | 53.4 | 24.0 | 28.7 | 95.5 |
| COD MG/L | 5560 | 2720 | 2770 | 9790 |
| RATIO KG/KKG | 114 | 55.6 | 56.6 | 200 |
| GREASE & OIL MG/L | 842 | 1110 | 232 | 3080 |
| RATIO KG/KKG | 17.2 | 22.6 | 4.74 | 62.9 |
| ORGANIC-N MG/L | 408 | 185 | 192 | 729 |
| RATIO KG/KKG | 8.35 | 3.77 | 3.93 | 14.9 |
| AMMONIA-N MG/L | 10.2 | 3.59 | 4.12 | 14.2 |
| RATIO KG/KKG | 0.208 | 0.073 | 0.084 | 0.290 |
| PH | 6.62 | 0.151 | 6.45 | 6.88 |
| TEMP DEG C | 15.4 | 0.705 | 14.8 | 16.7 |

PLANT CSN4
6 SAMPLES

## Table 55. SALMON CANNING PROCESS
## (HAND BUTCHER)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.02 | 0.818 | 0.286 | 2.62 |
| PROCESS TIME HR/DAY | 5.20 | — | 2.80 | 7.50 |
| FLOW L/SEC | 2.21 | 0.463 | 1.28 | 3.79 |
| (GAL/MIN) | 35.1 | 7.35 | 20.4 | 60.1 |
| FLOW RATIO L/KKG | 8980 | 2230 | 4240 | 16000 |
| (GAL/TON) | 2150 | 534 | 1020 | 3840 |
| SETT. SOLIDS ML/L | 1.92 | 0.625 | 0.732 | 3.10 |
| RATIO L/KFG | 17.3 | 5.61 | 6.57 | 27.8 |
| SCR. SOLIDS MG/L | — | — | — | — |
| RATIO KG/KKG | — | — | — | — |
| SUSP. SOLIDS MG/L | 342 | 60.5 | 220 | 491 |
| RATIO KG/KKG | 3.07 | 0.544 | 1.98 | 4.41 |
| 5 DAY BOD MG/L | 455 | 114 | 311 | 598 |
| RATIO KG/KKG | 4.08 | 1.02 | 2.79 | 5.37 |
| COD MG/L | 1260 | 310 | 616 | 2230 |
| RATIO KG/KKG | 11.3 | 2.78 | 5.53 | 20.0 |
| GREASE & OIL MG/L | 875 | — | — | — |
| RATIO KG/KKG | 7.85 | — | — | — |
| ORGANIC-N MG/L | 86.7 | 22.9 | 40.5 | 143 |
| RATIO KG/KKG | 0.779 | 0.206 | 0.364 | 1.28 |
| AMMONIA-N MG/L | 1.35 | 0.507 | 0.631 | 2.19 |
| RATIO KG/KKG | 0.012 | 0.005 | 0.006 | 0.020 |
| PH | 6.98 | — | — | — |
| TEMP DEG C | 13.7 | 2.11 | 12.4 | 15.0 |

PLANT CSN5
8 SAMPLES

## Table 56. SALMON CANNING PROCESS
## (HAND BUTCHER)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.786 | 0.684 | 0.203 | 1.81 |
| PROCESS TIME HR/DAY | 6.20 | — | 3.10 | 7.70 |
| FLOW L/SEC | 0.222 | 0.100 | 0.092 | 0.379 |
| (GAL/MIN) | 3.53 | 1.59 | 1.46 | 6.02 |
| FLOW RATIO L/KKG | 1780 | 646 | 958 | 3060 |
| (GAL/TON) | 427 | 155 | 230 | 735 |
| SETT. SOLIDS ML/L | 1.91 | 0.839 | 1.07 | 3.05 |
| RATIO L/KKG | 3.41 | 1.49 | 1.90 | 5.44 |
| SCR. SOLIDS MG/L | — | — | — | — |
| RATIO KG/KKG | — | — | — | — |
| SUSP. SOLIDS MG/L | 419 | 224 | 258 | 742 |
| RATIO KG/KKG | 0.746 | 0.399 | 0.460 | 1.32 |
| 5 DAY BOD MG/L | 1540 | 814 | 815 | 2260 |
| RATIO KG/KKG | 2.74 | 1.45 | 1.45 | 4.02 |
| COD MG/L | 2520 | 1070 | 1300 | 4650 |
| RATIO KG/KKG | 4.48 | 1.91 | 2.31 | 8.28 |
| GREASE & OIL MG/L | — | — | — | — |
| RATIO KG/KKG | — | — | — | — |
| ORGANIC-N MG/L | 185 | 82.5 | 96.9 | 358 |
| RATIO KG/KKG | 0.329 | 0.147 | 0.172 | 0.637 |
| AMMONIA-N MG/L | 2.44 | 1.30 | 0.871 | 4.98 |
| RATIO KG/KKG | 0.004 | 0.002 | 0.002 | 0.009 |
| PH | 6.97 | 0.064 | 6.92 | 7.06 |
| TEMP DEG C | 13.4 | 0.702 | 12.7 | 14.5 |

PLANT CS6M
6 SAMPLES

Table 53. SALMON CANNING PROCESS
(WITHOUT FLUMING)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.03 | 0.104 | 0.913 | 1.11 |
| PROCESS TIME HR/DAY | 6.10 | — | 2.30 | 9.50 |
| FLOW L/SEC | 11.9 | 0.880 | 11.0 | 12.8 |
| (GAL/MIN) | 189 | 14.0 | 175 | 203 |
| FLOW RATIO L/KKG | 47800 | 5040 | 42700 | 52800 |
| (GAL/TON) | 11500 | 1210 | 10200 | 12600 |
| SETT. SOLIDS ML/L | 12.2 | 4.20 | 7.36 | 15.0 |
| RATIO L/KKG | 582 | 200 | 352 | 715 |
| SCR. SOLIDS MG/L | 505 | 338 | 266 | 744 |
| RATIO KG/KKG | 24.1 | 16.1 | 12.7 | 35.5 |
| SUSP. SOLIDS MG/L | 384 | 66.4 | 342 | 460 |
| RATIO KG/KKG | 18.3 | 3.17 | 16.3 | 22.0 |
| 5 DAY BOD MG/L | 1030 | 88.7 | 930 | 1100 |
| RATIO KG/KKG | 49.1 | 4.24 | 44.4 | 52.7 |
| COD MG/L | 1990 | 387 | 1600 | 2370 |
| RATIO KG/KKG | 95.2 | 18.5 | 76.3 | 113 |
| GREASE & OIL MG/L | 110 | 23.8 | 94.1 | 137 |
| RATIO KG/KKG | 5.25 | 1.14 | 4.50 | 6.56 |
| ORGANIC-N MG/L | 152 | 39.1 | 117 | 194 |
| RATIO KG/KKG | 7.27 | 1.87 | 5.57 | 9.27 |
| AMMONIA-N MG/L | 3.58 | 0.365 | 3.23 | 3.95 |
| RATIO KG/KKG | 0.171 | 0.017 | 0.154 | 0.189 |
| PH | 6.51 | 0.103 | 6.41 | 6.65 |
| TEMP DEG C | 15.6 | -- | -- | -- |

PLANT CSN8
3 SAMPLES

The production rates averaged 27 kkg/day (30 tons/day) for the Alaska plants, however, this was considered to be lower than normal due to the poor 1973 season. Plant CS8H in the Northwest which was sampled from late July through early September, 1969 at a time of peak production averaged 53 kkg/day (58 tons/ day).

## Fresh/Frozen Salmon Process Wastewater Characteristics

Four fresh/frozen salmon operations in Alaska and three in the Northwest were investigated. The four Alaskan operations were monitored during August of 1973 which corresponded to a relatively heavy period of fresh/frozen salmon processing. All operations were located on the waterfront in urban areas, utilized a domestic water source, and discharged their effluent directly into a receiving body of water.

The three Northwest operations were monitored during September of 1973 near the end of the season, were located on the waterfront in metropolitan areas, utilized domestic water and discharged their effluent to the municipal treatment facilities.

Various species of both pre-dressed (troll caught) and round salmon were being processed during the sampling period.

## Wastewater Material Balance

Table 58 shows that the primary source of wastewater from the fresh/frozen salmon process is the wash tank operation, in which the eviscerated fish are cleansed of adhering blood, mesentaries, sea lice, and visceral particles. Also, depending upon the condition of the fish, a preliminary rinse of the round fish prior to butchering may also be implemented. This latter rinse is employed to reduce the amount of slime adhering to the fish to facilitate handling. The wash tank or wash tank plus pre-rinse contributes about 90 percent of the total effluent flow. The butchering table is essentially a dry operation except for short hose-downs of the area at the discretion of the crew. Some plants use small hoses attached to cleaning spoons and other use a small constant flow on the table.

Tables 59 through 62 show summary statistics of the waste water for the plants utilized in the subcategory summary. Figure 34 contains a normalized fesh/frozen salmon process plot of selected wastewater parameters from each plant sampled. Alaska plants are represented by codes FS1, FS2, FST1 and FST2, where FS represents a round fish process and FST a pre-dressed process. Northwest plants are represented by codes FS3, FST3, and FS4. It can be seen that the round fish processes have consistently higher waste loads in terms of BOD than the pre-dressed processes. The samples of the pre-dressed processes were taken at the same plants as the round fish processes, however, the waste flows could be separated since they are usually not conducted at the same time.

Table 58. Fresh/frozen round salmon process material balance

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) process water | 88 - 96% | 76 - 92% | 74 - 97% |
| b) washdown | 4 - 12% | 8 - 24% | 3 - 26% |
| Total effluent average FS1, FS2, FS3, FS4 | 3750 l/kkg | 2 kg/kkg | 0.8 kg/kkg |

Product Material Balance Summary

| End Products | % of Raw Product |
|---|---|
| Food products | |
| a) salmon | 65 - 80% |
| b) eggs | 5% |
| c) milk | 3% |
| By-product | |
| a) heads | 8% |
| b) viscera | 5 - 7% |
| Waste | 1 - 2% |

Average Production Rate, 16.4 kkg/day (18 tons/day)

## TABLE 59
## FROZEN SALMON PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.83 | 1.23 | 0.725 | 2.91 |
| PROCESS TIME HR/DAY | 6.75 | -- | 4.00 | 10.5 |
| FLOW L/SEC | 4.45 | 1.63 | 3.23 | 6.85 |
| (GAL/MIN) | 70.7 | 25.8 | 51.3 | 109 |
| FLOW RATIO L/KKG | 11500 | 5590 | 4640 | 17200 |
| (GAL/TON) | 2740 | 1340 | 1100 | 4130 |
| SETT. SOLIDS ML/L | 0.157 | 0.150 | 0.087 | 0.421 |
| RATIO L/KKG | 1.80 | 1.71 | 0.998 | 4.82 |
| SCR. SOLIDS MG/L | 114 | 18.8 | 90.4 | 136 |
| RATIO KG/KKG | 1.31 | 0.215 | 1.04 | 1.56 |
| SUSP. SOLIDS MG/L | 116 | 70.2 | 42.6 | 212 |
| RATIO KG/KKG | 1.33 | 0.804 | 0.488 | 2.42 |
| 5 DAY BOD MG/L | 259 | 105 | 106 | 331 |
| RATIO KG/KKG | 2.96 | 1.20 | 1.21 | 3.78 |
| COD MG/L | 552 | 277 | 191 | 865 |
| RATIO KG/KKG | 6.32 | 3.17 | 2.19 | 9.90 |
| GREASE & OIL MG/L | 26.0 | 13.9 | 49.9 | 76.0 |
| RATIO KG/KKG | 0.298 | 0.159 | 0.571 | 0.870 |
| ORGANIC-N MG/L | 48.6 | 28.3 | 15.0 | 83.5 |
| RATIO KG/KKG | 0.557 | 0.324 | 0.171 | 0.957 |
| AMMONIA-N MG/L | 1.75 | 0.745 | 0.986 | 2.77 |
| RATIO KG/KKG | 0.020 | 0.009 | 0.011 | 0.032 |
| PH | 6.27 | 0.280 | 5.91 | 7.04 |
| TEMP DEG C | 11.5 | 0.257 | 11.4 | 11.9 |

PLANT FS1
4 SAMPLES

Table 50. SALMON FRESH/FROZEN PROCESS
(ROUND)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 3.76 | 0.412 | 3.31 | 4.30 |
| PROCESS TIME HR/DAY | 7.38 | -- | 5.50 | 10.5 |
| FLOW L/SEC | 3.14 | 0.137 | 2.94 | 3.26 |
| (GAL/MIN) | 49.8 | 2.17 | 46.7 | 51.7 |
| FLOW RATIO L/KKG | 3390 | 480 | 2770 | 3940 |
| (GAL/TON) | 814 | 115 | 664 | 943 |
| SETT. SOLIDS ML/L | 0.717 | 0.401 | 0.346 | 1.24 |
| RATIO L/KKG | 2.44 | 1.36 | 1.17 | 4.20 |
| SCR. SOLIDS MG/L | 132 | 76.5 | 46.2 | 193 |
| RATIO KG/KKG | 0.449 | 0.260 | 0.157 | 0.654 |
| SUSP. SOLIDS MG/L | 271 | 47.5 | 200 | 299 |
| RATIO KG/KKG | 0.920 | 0.161 | 0.680 | 1.02 |
| 5 DAY BOD MG/L | 747 | 144 | 565 | 913 |
| RATIO KG/KKG | 2.54 | 0.489 | 1.92 | 3.10 |
| COD MG/L | 1540 | 325 | 1120 | 1920 |
| RATIO KG/KKG | 5.21 | 1.10 | 3.81 | 6.51 |
| GREASE & OIL MG/L | 41.0 | 6.46 | 34.3 | 47.6 |
| RATIO KG/KKG | 0.139 | 0.022 | 0.116 | 0.162 |
| ORGANIC-N MG/L | 122 | 27.2 | 91.0 | 151 |
| RATIO KG/KKG | 0.414 | 0.092 | 0.309 | 0.513 |
| AMMONIA-N MG/L | 3.85 | 0.928 | 2.79 | 4.72 |
| RATIO KG/KKG | 0.013 | 0.003 | 0.009 | 0.016 |
| PH | 6.59 | 0.210 | 6.40 | 7.07 |
| TEMP DEG C | 9.19 | 0.687 | 8.52 | 10.1 |

PLANT FS2
4 SAMPLES

Table 61. SALMON FRESH/FROZEN PROCESS
(ROUND)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 2.29 | 0.866 | 1.28 | 3.50 |
| PROCESS TIME HR/DAY | 3.67 | -- | 1.00 | 8.00 |
| FLOW L/SEC | 2.32 | 0.723 | 1.44 | 3.41 |
| (GAL/MIN) | 36.8 | 11.5 | 22.9 | 54.1 |
| FLOW RATIO L/KKG | 4330 | 1270 | 2570 | 7060 |
| (GAL/TON) | 1040 | 304 | 616 | 1690 |
| SETT. SOLIDS ML/L | 0.895 | 0.580 | 0.218 | 1.86 |
| RATIO L/KKG | 3.87 | 2.51 | 0.943 | 8.05 |
| SCR. SOLIDS MG/L | 385 | 290 | 121 | 828 |
| RATIO KG/KKG | 1.66 | 1.25 | 0.526 | 3.58 |
| SUSP. SOLIDS MG/L | 154 | 36.3 | 102 | 220 |
| RATIO KG/KKG | 0.665 | 0.157 | 0.443 | 0.950 |
| 5 DAY BOD MG/L | 404 | 95.0 | 254 | 539 |
| RATIO KG/KKG | 1.75 | 0.411 | 1.10 | 2.33 |
| COD MG/L | 765 | 150 | 502 | 951 |
| RATIO KG/KKG | 3.31 | 0.648 | 2.17 | 4.11 |
| GREASE & OIL MG/L | 39.9 | 9.03 | 25.9 | 52.7 |
| RATIO KG/KKG | 0.173 | 0.039 | 0.112 | 0.228 |
| ORGANIC-N MG/L | 48.2 | 20.3 | 12.4 | 74.5 |
| RATIO KG/KKG | 0.209 | 0.088 | 0.054 | 0.322 |
| AMMONIA-N MG/L | 2.49 | 0.600 | 1.66 | 3.66 |
| RATIO KG/KKG | 0.011 | 0.003 | 0.007 | 0.016 |
| PH | 7.03 | 0.192 | 6.64 | 7.30 |
| TEMP DEG C | 15.6 | 0.372 | 15.0 | 16.1 |

PLANT FS3
9 SAMPLES

## Table 62. SALMON FRESH/FROZEN PROCESS (ROUND)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 2.54 | 0.898 | 1.29 | 3.40 |
| PROCESS TIME HR/DAY | 8.88 | -- | 5.00 | 10.5 |
| FLOW L/SEC | 1.81 | 0.539 | 1.09 | 2.24 |
| (GAL/MIN) | 28.8 | 8.56 | 17.2 | 35.5 |
| FLOW RATIO L/KKG | 2920 | 555 | 2110 | 3360 |
| (GAL/TON) | 701 | 133 | 507 | 806 |
| SETT. SOLIDS ML/L | 0.720 | 0.589 | 0.113 | 1.29 |
| RATIO L/KKG | 2.10 | 1.72 | 0.329 | 3.78 |
| SCR. SOLIDS MG/L | 456 | 62.5 | 398 | 540 |
| RATIO KG/KKG | 1.33 | 0.183 | 1.16 | 1.58 |
| SUSP. SOLIDS MG/L | 236 | 72.2 | 133 | 300 |
| RATIO KG/KKG | 0.689 | 0.211 | 0.388 | 0.877 |
| 5 DAY BOD MG/L | 538 | 208 | 247 | 691 |
| RATIO KG/KKG | 1.57 | 0.609 | 0.722 | 2.02 |
| COD MG/L | 1070 | 459 | 500 | 1600 |
| RATIO KG/KKG | 3.13 | 1.34 | 1.46 | 4.67 |
| GREASE & OIL MG/L | 43.9 | 13.9 | 25.0 | 55.2 |
| RATIO KG/KKG | 0.128 | 0.041 | 0.073 | 0.161 |
| ORGANIC-N MG/L | 93.1 | 40.8 | 40.4 | 136 |
| RATIO KG/KKG | 0.272 | 0.119 | 0.118 | 0.397 |
| AMMONIA-N MG/L | 2.81 | 0.850 | 1.59 | 3.52 |
| RATIO KG/KKG | 0.008 | 0.002 | 0.005 | 0.010 |
| PH | 6.52 | 0.179 | 6.38 | 7.08 |
| TEMP DEG C | 15.7 | 0.261 | 15.6 | 16.0 |

PLANT F84
4 SAMPLES

The waste flows and loads for both pre-dressed and round fresh/frozen processes are relatively low and are comparable to the loads from the conventional bottom fish processes which will be discussed later in this section. No freezing salmon in the round processes were observed due to the poor season in Alaska, however, the waste loads from this process should be less than from the dressing operations.

## Product Material Balance

The production rate varies considerably due to raw product availability. The rates observed at the round fish operations averaged about 16 kkg/day (18 tons/day). Round fish processing predominates in both Alaska and the Northwest, however, large volumes of pre-dressed fish are handled on occasion as can be seen from the production rates for plant FST3. Table 58 shows that the food recovery of whole salmon varies from 65 to 80 percent. Chum and silver salmon yield approximately 75 percent; sockeye, 78 to 80 percent; and pinks, 65 to 70 percent. These figures refer only to round salmon which are eviscerated and beheaded. The recovery of finished product for troll caught fish is about ten to twelve percent higher for each species since they are eviscerated at sea. The recovery of eggs and milt represents about five and three percent of the round salmon weight, respectively. Other by-product recovery, such as the grinding and baggng of heads and viscera, is done only occasionally in Alaska and for the most part these solids are disposed of directly into the receiving water. The heads and viscera in the Northwest plants are usually collected for pet food or for reduction to fish meal.

## Bottom Fish and Miscellaneous Finfish Wastewater Characteristics

The wastewater characterization data from the bottom fish and miscellaneous finfish industry is organized into the conventional processes (essentially manual unit operations), the mechanized processes, and the Alaskan processes, because of the different methods, and regions involved.

## Non-Alaska Conventional Bottom Fish

Twelve conventional bottom fish, ground fish, and finfish plants in all non-Alaska regions were sampled in August and September, 1973. In addition, historical data were available from four Northwest operations (25). Bottom fish are often located in urban areas, use municipal water and sewer systems and operate year round with the species composition changing with the seasons. In general, there was no lack of fish during the monitoring periods except in New England where landings have been decreasing.

**Wastewater material balance**

There are a variety of conventional bottom fish processing operations. However, for the filleting process, which is considered to be the most important, there appears to be only two main options: the use of skinners, and/or scalers.

Table 63 shows the wastewater balance for three operations (B2, B4, B8) which used skinners most of the time. The skinners are mechanical and can constitute a large percentage (13 to 64 percent) of the flow and load (six to 36 percent of BOD) depending on the type used. The flow from the fillet tables is quite variable depending on water conservation practices. It is common practice for a small hose to be continually running at each filleting position. Fish are sometimes rinsed before filleting or eviscerating, and are usually dipped in a wash tank afterwards to clean and preserve the flesh. The flows from either of these operations is relatively small, however, the BOD and suspended solids loads can be moderately high.

Table 64 shows the wastewater balance for three operations (B1, B6, B11) which often used a descaler. It can be seen that the descaler can contribute a substantial flow and waste load. Descalers which use high pressure water jets in a revolving drum were observed to contribute high loads. One plant (B6) occasionally used a scaler which increased the water flow and waste load by a factor of four. This type of scaler was so large and contributed such a large waste load that it was not considered to be a conventional operation. In general, the waste loads were about the same whether skinners or scalers were used. Tables 69 through 81 summarize the wastewater characteristics for each of the conventional bottom fish processes used to determine the subcategory summary. Figure 44 presents a normalized convential bottom fish process plot of selected wastewater parameters for each plant monitored. Plants represented by codes B1 and B2 are small ground fish processes in New England, plants FNF1, FNF2, FNF3 are finfish processes in the mid-Atlantic region, FNF4 is a finfish process in the Gulf region, and B4 through B12 are bottom fish plants on the West Coast. Plant FNF3 was not considered typical since all the fish were handled in the round and no eviscerating or filleting operations were carried out on the one day of sampling. There is a relatively large variability in flow ratios and waste loads between all the plants. This is caused partly by different processing methods and mostly by different degrees of water conservation. The average flows and loads from all these plants are relatively low and are comparable to the fresh/frozen salmon process discussed previously.

**Product material balance**

The production rate of conventional bottom fish processes varies considerably. The average production level observed was 11 kkg/day (12 tons/day) but varied from 2.8 kkg/day to 31 kkg/day.

Table 63 shows the disposition of the raw product for food and by-products. The food product varies considerably (20 to 45 percent) depending on the species, season, and whether it is processed whole or filleted. Table 65 shows the recovery figures for various species of New England ground fish. All figures are for fillets unless noted.

The solid wastes (carcasses, viscera, etc.) are usually recovered for various by-products. In New England it is commonly used for lobster bait or sent to reduction plants. On the West Coast it is commonly used for pet or animal food or sent to reduction plants.

### Non-Alaska Mechanized Bottom Fish

Four mechanized plants which used a high percentage of machinery and water were sampled in the New England, Gulf and Northwest regions between August and October, 1973. It was a particularly good year for whiting in New England and large quantities of fish were available during the sampling period in August. The finfish process in the Gulf was sampled during October, 1973, which was during a period of higher than normal production.

The two whiting plants sampled (W1, W2) were considered to be typical mechanized operations where the fish were beheaded, descaled, and partially eviscerated by mechanical methods and relatively large water flows were used. The finfish process in the Gulf (CFC1) was processing croaker for fish flesh and was highly mechanized. The Northwest plant (B6) used conventional processing except for the large scaler which produced a high waste flow.

### Wastewater material balance

Table 66 shows the wastewater sources for a typical whiting process. The process water includes water from the storage bins, the beheader and the descaler, and is the largest source of wastewater. The largest portion of the process water is due to the fluming of fish from the storage bins to the processing line using a high pressure hose and elevator. The replacement of the hose by a dry conveyor system such as is used in the sardine plants would reduce the waste flow and load significantly. The visceral flume constitutes about 20 percent of the waste load and could be replaced by a dry conveyor system.

The unit operations of the fish flesh plant were not sampled, however, it is estimated that the highest loads came from the washdown which lasted several hours.

Table 63. Conventional bottom fish process material balance (with skinner)

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) skinner | 13 - 64% | 6 - 36% | 5 - 39% |
| b) fillet table | 22 - 83% | 43 - 76% | 39 - 80% |
| c) pre-rinse or dip tank | 1 - 13% | 7 - 26% | 5 - 34% |
| d) washdown | 3 - 21% | 4 - 20% | 7 - 21% |
| Total effluent average B2, B4, B8 | 8000 l/kkg | 2.8 kg/kkg | 1.8 kg/kkg |

Product Material Balance Summary

| End Products | % of Raw Product |
|---|---|
| Food products | 20 - 40% |
| By-products<br>a) carcass (reduction, animal food) | 55 - 75% |

Average Production Rate, 16.5 kkg/day (18 tons/day)

Table 64 . Conventional bottom fish process material balance (with descaler)

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) descaler | 42 - 66% | 56 - 61% | 26 - 70% |
| b) fillet table | 21 - 36% | 16 - 30% | 12 - 19% |
| c) pre-wash or dip tank | 3 - 10% | 4 - 8% | 4 - 8% |
| d) washdown | 7 - 18% | 6 - 19% | 7 - 18% |
| Total effluent average<br>B1, B10, B11 | 10,000 l/kkg | 2.5 kg/kkg | 1.6 kg/kkg |

Table 65. Percent recovery for New England ground fish

| Species (process) | % Recovery |
|---|---|
| Ocean perch | 29 |
| Cod (with skin) | 40 |
| Cod (boneless) | 35 |
| Cod (no skin) | 37 |
| Haddock | 40 |
| Haddock (no skin) | 37 |
| Sea catfish (dressed) | 45 |
| Sea catfish (filleted) | 30 |
| Pollock (with skin) | 45 |
| Pollock (no skin) | 40 |
| Flounder (small) | 20 |
| Flounder (large) | 30 |

Table 66 · Whiting freezing process material balance

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) process water | 70 - 75% | 74 - 77% | 74 - 78% |
| b) washdown | 3 - 8% | 2 - 5% | 2 - 6% |
| c) visceral flume | 22% | 21% | 20% |
| Total effluent average W1, W2 | 13,500 l/kkg | 14 kg/kkg | 11 kg/kkg |

Product Material Balance Summary

| End Products | % of Raw Product |
|---|---|
| Food Products | 50% |
| By-product<br>a) heads, scales, viscera (to reduction plant) | 48% |
| Waste | ≃ 2% |

Average Production Rate, 35 kkg/day (38 tons/day)

Table 67. Recovery of fillets and fish flesh from West Coast bottom fish (27)

| Species | % Recovery | |
|---|---|---|
| | Fillets | Flesh |
| English sole | 30 | 60 |
| Flounder | 31 | 47 |
| Ling cod | 28 | 43 |
| Pacific cod | -- | 38 |

Table 68. Halibut freezing process material balance

### Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) head cutter/grader | 3% | 11% | 10% |
| b) washer | 79% | 72% | 62% |
| c) washdown | 18% | 17% | 28% |
| Total effluent average FRH1 | 8600 l/kkg | 1.5 kg/kkg | 1.2 kg/kkg |

### Product Material Balance Summary

| End Products | % of Raw Product |
|---|---|
| Food products | 90% |
| By-products<br>a) heads | <br>10% |
| Wastes | minimal |

Average Production Rate, 33 kkg/day (36 tons/day)

### Table 69 . GROUND FISH FILLET PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.528 | 0.118 | 0.418 | 0.653 |
| PROCESS TIME HR/DAY | 5.83 | — | 4.50 | 7.50 |
| FLOW L/SEC | 0.226 | 0.050 | 0.188 | 0.284 |
| (GAL/MIN) | 3.59 | 0.797 | 2.98 | 4.51 |
| FLOW RATIO L/KKG | 1760 | 443 | 1210 | 2390 |
| (GAL/TON) | 422 | 106 | 290 | 572 |
| SETT. SOLIDS ML/L | 9.49 | 3.03 | 5.74 | 13.5 |
| RATIO L/KKG | 16.7 | 5.33 | 10.1 | 23.7 |
| SCR. SOLIDS MG/L | 4530 | 2640 | 2690 | 7650 |
| RATIO KG/KKG | 7.96 | 4.64 | 4.73 | 13.5 |
| SUSP. SOLIDS MG/L | 737 | 444 | 343 | 1420 |
| RATIO KG/KKG | 1.30 | 0.781 | 0.603 | 2.49 |
| 5 DAY BOD MG/L | 1010 | 397 | 584 | 1410 |
| RATIO KG/KKG | 1.78 | 0.699 | 1.03 | 2.49 |
| COD MG/L | 1590 | 742 | 757 | 2620 |
| RATIO KG/KKG | 2.79 | 1.31 | 1.33 | 4.62 |
| GREASE & OIL MG/L | 40.2 | 19.6 | 21.1 | 70.3 |
| RATIO KG/KKG | 0.071 | 0.034 | 0.037 | 0.124 |
| ORGANIC-N MG/L | 147 | 66.9 | 76.5 | 241 |
| RATIO KG/KKG | 0.259 | 0.118 | 0.135 | 0.425 |
| AMMONIA-N MG/L | 6.96 | 2.20 | 3.83 | 10.9 |
| RATIO KG/KKG | 0.012 | 0.004 | 0.007 | 0.019 |
| PH | 7.15 | 0.144 | 6.96 | 7.33 |
| TEMP DEG C | 20.9 | 2.41 | 18.7 | 22.5 |

PLANT B1
3 SAMPLES

### Table 70 · GROUND FISH FILLET PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.654 | 0.018 | 0.632 | 0.681 |
| PROCESS TIME HR/DAY | 6.84 | — | 4.70 | 7.70 |
| FLOW L/SEC | 2.27 | 0.004 | 2.27 | 2.28 |
| (GAL/MIN) | 36.0 | 0.059 | 36.0 | 36.1 |
| FLOW RATIO L/KKG | 13800 | 359 | 13300 | 14300 |
| (GAL/TON) | 3310 | 86.0 | 3190 | 3420 |
| SETT. SOLIDS ML/L | 4.69 | 3.89 | 1.46 | 10.1 |
| RATIO L/KKG | 64.7 | 53.7 | 20.2 | 139 |
| SCR. SOLIDS MG/L | — | — | — | — |
| RATIO KG/KKG | — | — | — | — |
| SUSP. SOLIDS MG/L | 186 | 115 | 58.0 | 366 |
| RATIO KG/KKG | 2.56 | 1.58 | 0.801 | 5.04 |
| 5 DAY BOD MG/L | 196 | 86.1 | 65.8 | 303 |
| RATIO KG/KKG | 2.71 | 1.19 | 0.908 | 4.19 |
| COD MG/L | 423 | 124 | 243 | 613 |
| RATIO KG/KKG | 5.83 | 1.71 | 3.35 | 8.46 |
| GREASE & OIL MG/L | 25.1 | 6.80 | 14.5 | 37.7 |
| RATIO KG/KKG | 0.347 | 0.094 | 0.200 | 0.520 |
| ORGANIC-N MG/L | 26.6 | 16.7 | 9.76 | 52.6 |
| RATIO KG/KKG | 0.367 | 0.230 | 0.135 | 0.726 |
| AMMONIA-N MG/L | 2.70 | 0.961 | 1.51 | 4.00 |
| RATIO KG/KKG | 0.037 | 0.013 | 0.021 | 0.055 |
| PH | 6.47 | 0.149 | 6.27 | 6.65 |
| TEMP DEG C | 16.0 | 2.55 | 12.5 | 17.9 |

PLANT B2
5 SAMPLES

## TABLE 71
## FINFISH PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 2.04 | 0.494 | 1.38 | 2.47 |
| PROCESS TIME HR/DAY | 6.48 | -- | 4.50 | 7.40 |
| FLOW L/SEC | 2.37 | 0.754 | 1.67 | 3.05 |
| (GAL/MIN) | 37.7 | 12.0 | 26.5 | 48.4 |
| FLOW RATIO L/KKG | 4370 | 1180 | 3020 | 5920 |
| (GAL/TON) | 1050 | 282 | 725 | 1420 |
| SETT. SOLIDS ML/L | 4.16 | 2.17 | 1.40 | 6.38 |
| RATIO L/KKG | 18.2 | 9.51 | 6.14 | 27.9 |
| SCR. SOLIDS MG/L | 579 | 403 | 252 | 899 |
| RATIO KG/KKG | 2.53 | 1.76 | 1.10 | 3.93 |
| SUSP. SOLIDS MG/L | 496 | 160 | 244 | 672 |
| RATIO KG/KKG | 2.17 | 0.701 | 1.07 | 2.94 |
| 5 DAY BOD MG/L | 1030 | 180 | 870 | 1190 |
| RATIO KG/KKG | 4.52 | 0.789 | 3.80 | 5.22 |
| COD MG/L | 1610 | 561 | 719 | 2240 |
| RATIO KG/KKG | 7.05 | 2.45 | 3.14 | 9.77 |
| GREASE & OIL MG/L | 292 | 115 | 166 | 434 |
| RATIO KG/KKG | 1.28 | 0.502 | 0.728 | 1.90 |
| ORGANIC-N MG/L | 76.8 | 20.6 | 50.6 | 102 |
| RATIO KG/KKG | 0.336 | 0.090 | 0.221 | 0.444 |
| AMMONIA-N MG/L | 7.19 | 2.33 | 4.88 | 10.5 |
| RATIO KG/KKG | 0.031 | 0.010 | 0.021 | 0.046 |
| PH | 6.78 | 0.121 | 6.60 | 6.94 |
| TEMP DEG C | 10.3 | 1.93 | 9.14 | 12.5 |

PLANT FNF1
4 SAMPLES

## Table 72. FINFISH PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.14 | 0.075 | 1.09 | 1.25 |
| PROCESS TIME HR/DAY | 8.00 | -- | -- | -- |
| FLOW L/SEC | 1.95 | 0.641 | 1.29 | 2.63 |
| (GAL/MIN) | 30.9 | 10.2 | 20.4 | 41.7 |
| FLOW RATIO L/KKG | 6790 | 2200 | 4540 | 8940 |
| (GAL/TON) | 1630 | 526 | 1090 | 2140 |
| SETT. SOLIDS ML/L | 6.18 | 3.02 | 2.36 | 9.67 |
| RATIO L/KKG | 41.9 | 20.5 | 16.0 | 65.6 |
| SCR. SOLIDS MG/L | 894 | 609 | 271 | 1630 |
| RATIO KG/KKG | 6.07 | 4.14 | 1.84 | 11.0 |
| SUSP. SOLIDS MG/L | 402 | 155 | 226 | 578 |
| RATIO KG/KKG | 2.72 | 1.05 | 1.54 | 3.92 |
| 5 DAY BOD MG/L | 864 | 317 | 429 | 1200 |
| RATIO KG/KKG | 5.86 | 2.15 | 2.91 | 8.12 |
| COD MG/L | 1470 | 472 | 973 | 1960 |
| RATIO KG/KKG | 9.98 | 3.20 | 6.61 | 13.3 |
| GREASE & OIL MG/L | 119 | 52.8 | 77.0 | 163 |
| RATIO KG/KKG | 0.806 | 0.358 | 0.522 | 1.11 |
| ORGANIC-N MG/L | 110 | 83.5 | 16.9 | 235 |
| RATIO KG/KKG | 0.745 | 0.567 | 0.114 | 1.59 |
| AMMONIA-N MG/L | 7.58 | 3.31 | 3.15 | 11.6 |
| RATIO KG/KKG | 0.051 | 0.022 | 0.021 | 0.079 |
| PH | 6.86 | 0.167 | 6.68 | 7.33 |
| TEMP DEG C | 24.3 | 0.791 | 23.7 | 25.2 |

PLANT FNF2
4 SAMPLES

### Table 73 . FINFISH PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.93 | 1.26 | 0.375 | 3.80 |
| PROCESS TIME HR/DAY | 5.50 | -- | 2.50 | 8.00 |
| FLOW L/SEC | 11.4 | 3.39 | 5.89 | 16.6 |
| (GAL/MIN) | 181 | 53.9 | 93.5 | 263 |
| FLOW RATIO L/KKG | 17500 | 5200 | 11100 | 28000 |
| (GAL/TON) | 4200 | 1250 | 2670 | 6710 |
| SETT. SOLIDS ML/L | 47.1 | 13.7 | 35.9 | 59.0 |
| RATIO L/KKG | 825 | 239 | 628 | 1030 |
| SCR. SOLIDS MG/L | 630 | 501 | 29.5 | 1730 |
| RATIO KG/KKG | 11.0 | 8.78 | 0.517 | 30.4 |
| SUSP. SOLIDS MG/L | 106 | 28.5 | 55.9 | 147 |
| RATIO KG/KKG | 1.65 | 0.499 | 0.980 | 2.57 |
| 5 DAY BOD MG/L | 318 | 125 | 128 | 465 |
| RATIO KG/KKG | 5.58 | 2.18 | 2.24 | 8.15 |
| COD MG/L | 571 | 211 | 231 | 811 |
| RATIO KG/KKG | 10.00 | 3.70 | 4.05 | 14.2 |
| GREASE & OIL MG/L | 35.7 | 11.9 | 15.9 | 53.7 |
| RATIO KG/KKG | 0.626 | 0.209 | 0.279 | 0.942 |
| ORGANIC-N MG/L | 56.0 | 25.7 | 18.7 | 89.4 |
| RATIO KG/KKG | 0.981 | 0.451 | 0.327 | 1.57 |
| AMMONIA-N MG/L | 3.95 | 1.68 | 1.82 | 7.52 |
| RATIO KG/KKG | 0.069 | 0.030 | 0.032 | 0.132 |
| PH | 7.12 | 0.161 | 6.85 | 7.45 |
| TEMP DEG C | 19.0 | 2.11 | 17.6 | 20.7 |

PLANT FNF4
5 SAMPLES

## Table 74. BOTTOM FISH FILLET PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.99 | -- | -- | -- |
| PROCESS TIME HR/DAY | 8.00 | -- | -- | -- |
| FLOW L/SEC | 1.41 | 0.141 | 1.21 | 1.54 |
| (GAL/MIN) | 22.4 | 2.24 | 19.2 | 24.5 |
| FLOW RATIO L/KKG | 2840 | 770 | 2150 | 3860 |
| (GAL/TON) | 681 | 184 | 516 | 924 |
| SETT. SOLIDS ML/L | 3.06 | 0.662 | 2.68 | 3.90 |
| RATIO L/KKG | 8.69 | 1.88 | 7.60 | 11.1 |
| SCR. SOLIDS MG/L | 264 | 54.6 | 216 | 323 |
| RATIO KG/KKG | 0.750 | 0.155 | 0.615 | 0.919 |
| SUSP. SOLIDS MG/L | 225 | 91.2 | 151 | 354 |
| RATIO KG/KKG | 0.638 | 0.259 | 0.428 | 1.01 |
| 5 DAY BOD MG/L | 388 | 140 | 229 | 565 |
| RATIO KG/KKG | 1.10 | 0.399 | 0.649 | 1.61 |
| COD MG/L | 741 | 313 | 455 | 1150 |
| RATIO KG/KKG | 2.11 | 0.888 | 1.29 | 3.27 |
| GREASE & OIL MG/L | 64.2 | 20.7 | 41.5 | 91.6 |
| RATIO KG/KKG | 0.182 | 0.059 | 0.118 | 0.260 |
| ORGANIC-N MG/L | 49.7 | 23.8 | 28.5 | 82.2 |
| RATIO KG/KKG | 0.141 | 0.068 | 0.081 | 0.234 |
| AMMONIA-N MG/L | 3.55 | 0.893 | 2.77 | 4.53 |
| RATIO KG/KKG | 0.010 | 0.003 | 0.008 | 0.013 |
| PH | 7.19 | 0.115 | 7.08 | 7.34 |
| TEMP DEG C | 16.5 | 1.73 | 14.7 | 17.4 |

PLANT B4
4 SAMPLES

## Table 75. BOTTOM FISH FILLET PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 2.61 | 0.633 | 1.66 | 3.34 |
| PROCESS TIME HR/DAY | 8.00 | -- | -- | -- |
| FLOW L/SEC | 3.62 | 0.712 | 2.38 | 4.52 |
| (GAL/MIN) | 57.5 | 11.3 | 37.7 | 71.7 |
| FLOW RATIO L/KKG | 5880 | 1790 | 3920 | 9310 |
| (GAL/TON) | 1410 | 428 | 939 | 2230 |
| SETT. SOLIDS ML/L | 4.88 | 1.82 | 2.16 | 7.24 |
| RATIO L/KKG | 28.7 | 10.7 | 12.7 | 42.6 |
| SCR. SOLIDS MG/L | 202 | 33.7 | 163 | 241 |
| RATIO KG/KKG | 1.19 | 0.198 | 0.956 | 1.42 |
| SUSP. SOLIDS MG/L | 171 | 62.6 | 85.9 | 266 |
| RATIO KG/KKG | 1.00 | 0.368 | 0.505 | 1.56 |
| 5 DAY BOD MG/L | 346 | 157 | 153 | 581 |
| RATIO KG/KKG | 2.04 | 0.922 | 0.901 | 3.42 |
| COD MG/L | 608 | 239 | 300 | 914 |
| RATIO KG/KKG | 3.58 | 1.41 | 1.76 | 5.38 |
| GREASE & OIL MG/L | 60.9 | 18.1 | 34.9 | 89.0 |
| RATIO KG/KKG | 0.358 | 0.106 | 0.205 | 0.523 |
| ORGANIC-N MG/L | 44.9 | 22.4 | 20.7 | 80.0 |
| RATIO KG/KKG | 0.264 | 0.132 | 0.121 | 0.471 |
| AMMONIA-N MG/L | 2.48 | 1.19 | 1.25 | 4.25 |
| RATIO KG/KKG | 0.015 | 0.007 | 0.007 | 0.025 |
| PH | 7.09 | 0.146 | 6.89 | 7.36 |
| TEMP DEG C | 16.8 | 0.251 | 16.7 | 17.0 |

PLANT B5
5 SAMPLES

Table 76 . BOTTOM FISH FILLET PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.30 | 0.007 | 1.29 | 1.30 |
| PROCESS TIME HR/DAY | 7.00 | -- | 5.00 | 8.00 |
| FLOW L/SEC | 3.19 | 0.672 | 2.53 | 3.88 |
| (GAL/MIN) | 50.7 | 10.7 | 40.2 | 61.6 |
| FLOW RATIO L/KKG | 9990 | 2050 | 7950 | 12100 |
| (GAL/TON) | 2390 | 492 | 1910 | 2890 |
| SETT. SOLIDS ML/L | 2.05 | 0.515 | 1.51 | 2.54 |
| RATIO L/KKG | 20.5 | 5.15 | 15.1 | 25.3 |
| SCR. SOLIDS MG/L | 63.0 | 5.34 | 59.6 | 69.2 |
| RATIO KG/KKG | 0.630 | 0.053 | 0.596 | 0.691 |
| SUSP. SOLIDS MG/L | 96.2 | 33.1 | 60.2 | 125 |
| RATIO KG/KKG | 0.961 | 0.331 | 0.601 | 1.25 |
| 5 DAY BOD MG/L | 198 | 90.9 | 102 | 283 |
| RATIO KG/KKG | 1.97 | 0.909 | 1.02 | 2.83 |
| COD MG/L | 359 | 171 | 186 | 529 |
| RATIO KG/KKG | 3.59 | 1.71 | 1.86 | 5.28 |
| GREASE & OIL MG/L | 22.2 | 6.33 | 16.9 | 29.2 |
| RATIO KG/KKG | 0.222 | 0.063 | 0.169 | 0.292 |
| ORGANIC-N MG/L | 31.8 | 15.8 | 15.9 | 47.6 |
| RATIO KG/KKG | 0.318 | 0.158 | 0.159 | 0.475 |
| AMMONIA-N MG/L | 1.74 | 0.818 | 0.844 | 2.45 |
| RATIO KG/KKG | 0.017 | 0.008 | 0.008 | 0.024 |
| PH | 7.26 | -- | -- | -- |
| TEMP DEG C | 16.3 | 1.12 | 15.6 | 17.0 |

PLANT B7
3 SAMPLES

## Table 77. BOTTOM FISH FILLET PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 5.12 | 1.00 | 3.73 | 6.10 |
| PROCESS TIME HR/DAY | 6.75 | -- | 5.50 | 8.00 |
| FLOW L/SEC | 9.08 | 0.807 | 7.92 | 9.84 |
| (GAL/MIN) | 144 | 12.8 | 126 | 156 |
| FLOW RATIO L/KKG | 7550 | 1020 | 6150 | 8910 |
| (GAL/TON) | 1810 | 245 | 1480 | 2140 |
| SETT. SOLIDS ML/L | 3.68 | 0.764 | 2.85 | 4.53 |
| RATIO L/KKG | 27.8 | 5.77 | 21.5 | 34.2 |
| SCR. SOLIDS MG/L | 203 | 154 | 67.0 | 383 |
| RATIO KG/KKG | 1.53 | 1.16 | 0.506 | 2.89 |
| SUSP. SOLIDS MG/L | 301 | 108 | 176 | 464 |
| RATIO KG/KKG | 2.27 | 0.815 | 1.33 | 3.51 |
| 5 DAY BOD MG/L | 594 | 208 | 388 | 934 |
| RATIO KG/KKG | 4.48 | 1.57 | 2.93 | 7.05 |
| COD MG/L | 1050 | 308 | 680 | 1530 |
| RATIO KG/KKG | 7.91 | 2.32 | 5.13 | 11.5 |
| GREASE & OIL MG/L | 86.7 | 65.2 | 34.9 | 176 |
| RATIO KG/KKG | 0.655 | 0.492 | 0.263 | 1.33 |
| ORGANIC-N MG/L | 73.4 | 29.8 | 28.4 | 106 |
| RATIO KG/KKG | 0.555 | 0.225 | 0.215 | 0.797 |
| AMMONIA-N MG/L | 4.30 | 2.57 | 2.11 | 8.41 |
| RATIO KG/KKG | 0.032 | 0.019 | 0.016 | 0.064 |
| PH | 7.13 | 0.128 | 7.01 | 7.38 |
| TEMP DEG C | 16.6 | 0.711 | 16.1 | 17.0 |

PLANT R6
4 SAMPLES

## Table 78. BOTTOM FISH FILLET PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.96 | 0.362 | 1.70 | 2.21 |
| PROCESS TIME HR/DAY | 7.00 | -- | 6.00 | 8.00 |
| FLOW L/SEC | 7.53 | 0.490 | 7.18 | 7.88 |
| (GAL/MIN) | 120 | 7.76 | 114 | 125 |
| FLOW RATIO L/KKG | 15700 | 3890 | 12900 | 18400 |
| (GAL/TON) | 3750 | 934 | 3090 | 4410 |
| SETT. SOLIDS ML/L | 4.29 | 1.41 | 3.30 | 5.29 |
| RATIO L/KKG | 67.2 | 22.1 | 51.6 | 82.8 |
| SCR. SOLIDS MG/L | 94.1 | 86.5 | 33.0 | 155 |
| RATIO KG/KKG | 1.47 | 1.35 | 0.516 | 2.43 |
| SUSP. SOLIDS MG/L | 161 | 91.5 | 96.4 | 226 |
| RATIO KG/KKG | 2.52 | 1.43 | 1.51 | 3.53 |
| 5 DAY BOD MG/L | 263 | 99.0 | 193 | 333 |
| RATIO KG/KKG | 4.11 | 1.55 | 3.02 | 5.21 |
| COD MG/L | 451 | 214 | 299 | 602 |
| RATIO KG/KKG | 7.05 | 3.35 | 4.68 | 9.42 |
| GREASE & OIL MG/L | 36.4 | 8.38 | 30.5 | 42.3 |
| RATIO KG/KKG | 0.570 | 0.131 | 0.477 | 0.663 |
| ORGANIC-N MG/L | 35.4 | 12.4 | 26.6 | 44.2 |
| RATIO KG/KKG | 0.554 | 0.195 | 0.417 | 0.692 |
| AMMONIA-N MG/L | 1.58 | 0.257 | 1.40 | 1.76 |
| RATIO KG/KKG | 0.025 | 0.004 | 0.022 | 0.028 |
| PH | 7.26 | 0.037 | 7.23 | 7.28 |
| TEMP DEG C | 16.1 | -- | -- | -- |

PLANT B9
2 SAMPLES

Table 79 . BOTTOM FISH FILLET PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.25 | 0.419 | 0.741 | 1.88 |
| PROCESS TIME HR/DAY | 6.70 | -- | 4.20 | 9.30 |
| FLOW L/SEC | 6.58 | 1.20 | 5.08 | 9.14 |
| (GAL/MIN) | 104 | 19.0 | 80.7 | 145 |
| FLOW RATIO L/KKG | 22700 | 5910 | 13800 | 31700 |
| (GAL/TON) | 5440 | 1420 | 3310 | 7610 |
| SETT. SOLIDS ML/L | 1.72 | 0.814 | 0.800 | 2.92 |
| RATIO L/KKG | 39.0 | 18.5 | 18.2 | 66.4 |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 79.1 | 21.4 | 46.5 | 124 |
| RATIO KG/KKG | 1.80 | 0.487 | 1.06 | 2.82 |
| 5 DAY BOD MG/L | 156 | 8.07 | 148 | 164 |
| RATIO KG/KKG | 3.53 | 0.183 | 3.35 | 3.72 |
| COD MG/L | 298 | 89.8 | 171 | 492 |
| RATIO KG/KKG | 6.78 | 2.04 | 3.89 | 11.2 |
| GREASE & OIL MG/L | 3.92 | -- | -- | -- |
| RATIO KG/KKG | 0.089 | -- | -- | -- |
| ORGANIC-N MG/L | 22.5 | 7.72 | 12.8 | 39.0 |
| RATIO KG/KKG | 0.511 | 0.175 | 0.290 | 0.886 |
| AMMONIA-N MG/L | 1.21 | 0.362 | 0.622 | 1.90 |
| RATIO KG/KKG | 0.027 | 0.008 | 0.014 | 0.043 |
| PH | 6.59 | 0.262 | 6.10 | 7.00 |
| TEMP DEG C | 14.4 | 2.73 | 10.8 | 18.8 |

PLANT B10
9 SAMPLES

Table 80 . BOTTOM FISH FILLET PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.08 | 0.318 | 0.694 | 1.89 |
| PROCESS TIME HR/DAY | 7.08 | -- | 3.80 | 9.20 |
| FLOW L/SEC | 1.50 | 0.368 | 0.750 | 2.51 |
| (GAL/MIN) | 23.8 | 5.84 | 11.9 | 39.8 |
| FLOW RATIO L/KKG | 5630 | 1420 | 2150 | 9420 |
| (GAL/TON) | 1350 | 340 | 516 | 2260 |
| SETT. SOLIDS ML/L | 3.63 | 1.78 | 1.33 | 8.38 |
| RATIO L/KKG | 20.5 | 10.0 | 7.49 | 47.2 |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 285 | 96.9 | 101 | 490 |
| RATIO KG/KKG | 1.61 | 0.546 | 0.571 | 2.76 |
| 5 DAY BOD MG/L | 381 | -- | -- | -- |
| RATIO KG/KKG | 2.14 | -- | -- | -- |
| COD MG/L | 902 | 334 | 218 | 1560 |
| RATIO KG/KKG | 5.08 | 1.88 | 1.23 | 8.81 |
| GREASE & OIL MG/L | 143 | -- | -- | -- |
| RATIO KG/KKG p | 0.805 | -- | -- | -- |
| ORGANIC-N MG/L | 74.0 | 22.1 | 32.0 | 118 |
| RATIO KG/KKG | 0.417 | 0.125 | 0.180 | 0.666 |
| AMMONIA-N MG/L | 4.93 | 1.88 | 1.55 | 10.4 |
| RATIO KG/KKG | 0.028 | 0.011 | 0.009 | 0.058 |
| PH | 5.82 | 0.241 | 5.40 | 7.16 |
| TEMP DEG C | 12.4 | 3.85 | 7.10 | 17.5 |

PLANT B11
11 SAMPLES

### Table 81 . BOTTOM FISH FILLET PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.40 | 0.432 | 0.800 | 2.13 |
| PROCESS TIME HR/DAY | 6.60 | -- | 4.00 | 9.00 |
| FLOW L/SEC | 1.58 | 0.250 | 0.971 | 2.07 |
| (GAL/MIN) | 25.1 | 3.97 | 15.4 | 32.9 |
| FLOW RATIO L/KKG | 4690 | 653 | 3500 | 6300 |
| (GAL/TON) | 1120 | 156 | 838 | 1510 |
| SETT. SOLIDS ML/L | 4.78 | 1.99 | 1.87 | 10.0 |
| RATIO L/KKG | 22.4 | 9.31 | 8.78 | 46.9 |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 322 | 70.6 | 184 | 525 |
| RATIO KG/KKG | 1.51 | 0.331 | 0.865 | 2.46 |
| 5 DAY BOD MG/L | 597 | -- | -- | -- |
| RATIO KG/KKG | 2.80 | -- | -- | -- |
| COD MG/L | 1300 | 407 | 668 | 2160 |
| RATIO KG/KKG | 6.08 | 1.91 | 3.13 | 10.1 |
| GREASE & OIL MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| ORGANIC-N MG/L | 107 | 32.7 | 54.8 | 160 |
| RATIO KG/KKG | 0.504 | 0.153 | 0.257 | 0.749 |
| AMMONIA-N MG/L | 6.42 | 2.58 | 2.36 | 12.0 |
| RATIO KG/KKG | 0.030 | 0.012 | 0.011 | 0.056 |
| PH | 5.89 | 0.222 | 5.57 | 6.59 |
| TEMP DEG C | 13.2 | 3.65 | 9.00 | 17.2 |

PLANT B12
7 SAMPLES

Tables 82, 83, and 84 summarize the wastewater characteristics from the mechanized plants which were used to determine the subcategory average. Figure 45 contains a normalized mechanized bottom fish process plot for selected wastewater parameters for each plant sampled.

## Product material balance

The production levels for typical whiting processes are relatively high. The average rate observed at the two plants sampled was 35 kkg/day (38 tons/day). Table 66 shows that the food recovery is higher for the whiting than other ground fish since only the head and viscera are removed. The solid waste is typically sent to reduction plants.

The production loads at the fish flesh process observed was lower, averaging 5.0 kkg/day (5.5 tons/day), however, the industry is expanding and it is predicted that production levels will increase. Typical food recovery figures for fish flesh operations using various species of bottom fish are listed in Table 67.

## Alaska Bottom Fish

The halibut is the most significant bottom fish processed in Alaska. Two halibut processes in urban areas of Alaska were monitored during July and August, 1973. The sampling period was in the middle of the season; however, the operations were intermittent due to a poor harvest. Two typical halibut processes were observed; whole freezing and fletching, but neither contributes a very high waste load.

## Wastewater material balance

Intake water was obtained from the municipal water system and discharges were either to municipal sewer systems or to the receiving water.

Table 68 shows the wastewater balance for a whole halibut freezing operation. The first unit operation is the grading and head cutting operation, which produces a minimal waste load comprising about three percent of the total flow and a somewhat larger percentage of the BOD and suspended solids loads. One plant observed used no water for this operation. The washing operation is handled in two different manners, and they produce substantially different waste flows. In one system, a continuous spray washer is used, as well as spray hoses for the gut cavity. For this, the flow and waste loads are rather large, comprising about 80 percent of the total flow and 70 percent of the BOD. The other method involves washing the fish in shallow tanks with brushes. This produces a much lower flow, but higher waste concentrations such that the waste load is similar to the other method. For both processes observed, the washdown was similar, producing about 20 percent of the total flow and waste loads. The waste flows from a halibut fletching process are minimal, with the washdown around the trim table constituting about 80 percent of the total BOD load. Table 85 and 86 summarize the wastewater characteristics for the two halibut processes sampled.

Product material balance

The production rates at halibut processing plants can be quite high. The average production for the whole freezing operation was 33 kkg/day (36 tons/day), while the average production for the fletching operation was 5.6 kkg/day (6.2 tons/day).

Solid waste from the freezing operation is minimal since the only non-food product is the heads which are often used for bait. There is no visceral waste since the fish are eviscerated at sea. Solid waste from the fletching operation is about 40 percent which consists of the carcasses and heads which may be used for bait or disposed to the receiving waters.

## SARDINE CANNING PROCESS WASTEWATER CHARACTERISTICS

Two sardine canning plants were monitored during the month of September, 1973. Due to the declining herring fishery, some difficulty was encountered with raw product availability during September, 1973, hence the operations were intermittent and fewer samples were obtained than originally planned. However, additional historical data were obtained from the Edward C. Jordan Company, of Portland, Maine who conducted studies for the Maine Sardine Council over a period from the fall of 1970 to early 1971.

### Wastewater Material Balance

Table 87 shows the wastewater material balance for a typical sardine canning plant. Each of the plants sampled used city water for in-plant processing. Available surface water (salt or brackish) was used to transport the fish from trucks or boats to brine storage tanks.

Conveying fish to the packing tables was observed to contribute 18 to 62 percent of the water . Another large source of waste loading is the stickwater from the precooking operation. The flow is quite low, however, the BOD and suspended solid loadings are significant. A very great reduction in BOD, suspended solids, and grease and oil could be made by storing the stickwater from the precook operation and transporting it to a reduction plant for oil and solubles recovory. The sample data indicated that approximately 70 percent of the total grease and

## Table 82. WHITING FREEZING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 7.10 | 1.41 | 4.00 | 8.05 |
| PROCESS TIME HR/DAY | 8.76 | -- | 5.00 | 10.5 |
| FLOW L/SEC | 17.2 | 2.51 | 14.9 | 21.5 |
| (GAL/MIN) | 274 | 39.8 | 237 | 341 |
| FLOW RATIO L/KKG | 10200 | 3730 | 7500 | 18100 |
| (GAL/TON) | 2450 | 894 | 1800 | 4340 |
| SETT. SOLIDS ML/L | 8.77 | 2.21 | 5.90 | 12.0 |
| RATIO L/KKG | 89.6 | 22.6 | 60.3 | 122 |
| SCR. SOLIDS MG/L | 1100 | 722 | 209 | 2140 |
| RATIO KG/KKG | 11.3 | 7.37 | 2.14 | 21.9 |
| SUSP. SOLIDS MG/L | 859 | 282 | 491 | 1320 |
| RATIO KG/KKG | 8.77 | 2.88 | 5.02 | 13.4 |
| 5 DAY BOD MG/L | 1160 | 353 | 683 | 1820 |
| RATIO KG/KKG | 11.8 | 3.60 | 6.98 | 18.6 |
| COD MG/L | 2040 | 789 | 1200 | 3250 |
| RATIO KG/KKG | 20.8 | 8.06 | 12.3 | 33.2 |
| GREASE & OIL MG/L | 270 | 178 | 107 | 559 |
| RATIO KG/KKG | 2.75 | 1.82 | 1.09 | 5.71 |
| ORGANIC-N MG/L | 98.4 | 36.2 | 52.2 | 146 |
| RATIO KG/KKG | 1.01 | 0.370 | 0.533 | 1.49 |
| AMMONIA-N MG/L | 3.70 | 0.949 | 2.01 | 4.78 |
| RATIO KG/KKG | 0.038 | 0.010 | 0.020 | 0.049 |
| PH | 6.93 | 0.028 | 6.91 | 6.97 |
| TEMP DEG C | 19.6 | 1.58 | 17.8 | 20.5 |

PLANT W1
7 SAMPLES

## Table 83. WHITING FREEZING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 4.71 | 1.13 | 3.60 | 6.27 |
| PROCESS TIME HR/DAY | 3.15 | — | 2.30 | 4.80 |
| FLOW L/SEC | 19.3 | 2.16 | 16.1 | 21.7 |
| (GAL/MIN) | 307 | 34.4 | 255 | 344 |
| FLOW RATIO L/KKG | 16900 | 3530 | 13000 | 21200 |
| (GAL/TON) | 4050 | 845 | 3120 | 5090 |
| SETT. SOLIDS ML/L | 5.40 | 3.24 | 1.77 | 8.30 |
| RATIO L/KKG | 91.2 | 54.7 | 29.9 | 140 |
| SCR. SOLIDS MG/L | 649 | 587 | 234 | 1060 |
| RATIO KG/KKG | 11.0 | 9.91 | 3.95 | 18.0 |
| SUSP. SOLIDS MG/L | 778 | 212 | 492 | 1040 |
| RATIO KG/KKG | 13.1 | 3.57 | 8.31 | 17.6 |
| 5 DAYPBOD MG/L | 1010 | 400 | 434 | 1400 |
| RATIO KG/KKG | 17.0 | 6.75 | 7.32 | 23.6 |
| COD MG/L | 2150 | 764 | 974 | 2760 |
| RATIO KG/KKG | 36.3 | 12.9 | 16.4 | 46.6 |
| GREASE & OIL MG/L | 323 | 177 | 104 | 494 |
| RATIO KG/KKG | 5.44 | 2.99 | 1.76 | 8.34 |
| ORGANIC-N MG/L | 79.9 | 19.4 | 53.2 | 99.7 |
| RATIO KG/KKG | 1.35 | 0.328 | 0.899 | 1.68 |
| AMMONIA-N MG/L | 4.04 | 1.18 | 2.94 | 5.37 |
| RATIO KG/KKG | 0.068 | 0.020 | 0.050 | 0.091 |
| PH | 7.71 | — | — | — |
| TEMP DEG C | — | — | — | — |

PLANT W2
4 SAMPLES

Table 84 . CROAKER FISH FLESH PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.801 | 0.119 | 0.712 | 0.937 |
| PROCESS TIME HR/DAY | 6.90 | -- | 2.50 | 8.00 |
| FLOW L/SEC | 3.26 | 1.82 | 1.82 | 6.45 |
| (GAL/MIN) | 51.8 | 28.9 | 28.9 | 102 |
| FLOW RATIO L/KKG | 16700 | 10700 | 10200 | 35600 |
| (GAL/TON) | 4010 | 2570 | 2430 | 8530 |
| SETT. SOLIDS ML/L | 8.27 | 3.07 | 5.76 | 13.0 |
| RATIO L/KKG | 138 | 51.4 | 96.3 | 217 |
| SCR. SOLIDS MG/L | 344 | 190 | 116 | 575 |
| RATIO KG/KKG | 5.76 | 3.17 | 1.94 | 9.62 |
| SUSP. SOLIDS MG/L | 252 | 148 | 74.1 | 468 |
| RATIO KG/KKG | 4.21 | 2.48 | 1.24 | 7.83 |
| 5 DAY BOD MG/L | 678 | 291 | 395 | 1110 |
| RATIO KG/KKG | 11.3 | 4.86 | 6.60 | 18.5 |
| COD MG/L | 1210 | 566 | 536 | 1980 |
| RATIO KG/KKG | 20.3 | 9.47 | 8.96 | 33.1 |
| GREASE & OIL MG/L | 91.3 | 64.8 | 11.5 | 187 |
| RATIO KG/KKG | 1.53 | 1.08 | 0.193 | 3.13 |
| ORGANIC-N MG/L | 124 | 47.1 | 62.5 | 175 |
| RATIO KG/KKG | 2.08 | 0.788 | 1.05 | 2.93 |
| AMMONIA-N MG/L | 4.84 | 2.00 | 3.27 | 8.30 |
| RATIO KG/KKG | 0.081 | 0.033 | 0.055 | 0.139 |
| PH | 7.23 | 0.191 | 6.97 | 7.75 |
| TEMP DEG C | 21.6 | 1.33 | 20.0 | 23.3 |

PLANT CFC1
5 SAMPLES

## Table 85. HALIBUT FREEZING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 7.64 | 3.32 | 3.91 | 13.2 |
| PROCESS TIME HR/DAY | 4.76 | — | 2.50 | 9.50 |
| FLOW L/SEC | 13.1 | 0.681 | 11.7 | 14.0 |
| (GAL/MIN) | 208 | 10.8 | 185 | 222 |
| FLOW RATIO L/KKG | 8580 | 1920 | 5610 | 10600 |
| (GAL/TON) | 2060 | 460 | 1340 | 2540 |
| SETT. SOLIDS ML/L | 0.328 | 0.259 | 0.132 | 1.03 |
| RATIO L/KKG | 2.81 | 2.22 | 1.13 | 8.87 |
| SCR. SOLIDS MG/L | 944 | 321 | 542 | 1290 |
| RATIO KG/KKG | 8.10 | 2.75 | 4.65 | 11.1 |
| SUSP. SOLIDS MG/L | 137 | 38.9 | 81.6 | 206 |
| RATIO KG/KKG | 1.18 | 0.334 | 0.700 | 1.76 |
| 5 DAY BOD MG/L | 179 | 47.2 | 104 | 255 |
| RATIO KG/KKG | 1.54 | 0.405 | 0.893 | 2.18 |
| COD MG/L | 402 | 116 | 243 | 613 |
| RATIO KG/KKG | 3.44 | 0.998 | 2.08 | 5.26 |
| GREASE & OIL MG/L | 59.4 | 21.8 | 28.5 | 99.1 |
| RATIO KG/KKG | 0.510 | 0.187 | 0.244 | 0.850 |
| ORGANIC-N MG/L | 24.8 | 13.7 | 3.53 | 54.8 |
| RATIO KG/KKG | 0.213 | 0.117 | 0.030 | 0.470 |
| AMMONIA-N MG/L | 3.29 | 1.58 | 1.53 | 6.03 |
| RATIO KG/KKG | 0.028 | 0.014 | 0.013 | 0.052 |
| PH | 6.95 | 0.057 | 6.85 | 7.02 |
| TEMP DEG C | 10.8 | 0.282 | 10.5 | 11.1 |

PLANT FRH1
9 SAMPLES

## Table 86 . HALIBUT FLETCHING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.13 | 0.136 | 1.00 | 1.27 |
| PROCESS TIME HR/DAY | 5.50 | -- | 2.50 | 7.00 |
| FLOW L/SEC | 0.756 | 0.118 | 0.684 | 0.893 |
| (GAL/MIN) | 12.0 | 1.88 | 10.9 | 14.2 |
| FLOW RATIO L/KKG | 2380 | 565 | 2010 | 3040 |
| (GAL/TON) | 571 | 135 | 482 | 729 |
| SETT. SOLIDS ML/L | 20.6 | 2.65 | 18.9 | 23.8 |
| RATIO L/KKG | 49.1 | 6.32 | 45.0 | 56.8 |
| SCR. SOLIDS MG/L | 314 | 213 | 163 | 465 |
| RATIO KG/KKG | 0.749 | 0.508 | 0.389 | 1.11 |
| SUSP. SOLIDS MG/L | 775 | 75.4 | 699 | 875 |
| RATIO KG/KKG | 1.85 | 0.180 | 1.67 | 2.08 |
| 5 DAY BOD MG/L | 876 | 52.1 | 813 | 928 |
| RATIO KG/KKG | 2.09 | 0.124 | 1.94 | 2.21 |
| COD MG/L | 1870 | 121 | 1720 | 2000 |
| RATIO KG/KKG | 4.46 | 0.289 | 4.09 | 4.77 |
| GREASE & OIL MG/L | 33.6 | 1.19 | 32.1 | 35.0 |
| RATIO KG/KKG | 0.080 | 0.003 | 0.076 | 0.083 |
| ORGANIC-N MG/L | 174 | 12.0 | 158 | 184 |
| RATIO KG/KKG | 0.415 | 0.028 | 0.377 | 0.437 |
| AMMONIA-N MG/L | 3.87 | 1.11 | 2.72 | 5.17 |
| RATIO KG/KKG | 0.009 | 0.003 | 0.006 | 0.012 |
| PH | 6.24 | 0.123 | 6.13 | 6.44 |
| TEMP DEG C | 9.44 | -- | -- | -- |

PLANT FFH1
3 SAMPLES

Table 87 . Sardine canning process material balance

## Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) flume (boat to storage) | 14 - 46% | 12 - 28% | 11 - 57% |
| b) flume (brine tank to table) | 18 - 62% | 14 - 22% | 16 - 30% |
| c) pre-cook can dump | <1 - 4% | 28 - 67% | 14 - 51% |
| d) can wash | 3 - 4% | 16 - 23% | 9 - 10% |
| e) retort | 8 - 53% | 1 - 2% | 1 - 4% |
| f) washdown | 1 - 10% | 1 - 6% | 1 - 12% |
| Total effluent average SA1, SA2, SA3, SA4 | 7600 l/kkg | 10 kg/kkg | 7 kg/kkg |

## Product Material Balance Summary

| End Products | % of Raw Product |
|---|---|
| Food products | 30 - 60% |
| By-products | |
| a) heads and tails (reduction or bait) | 35 - 65% |
| b) scales | 1 - 2% |

Average Production Rate, 31 kkg/day (34 tons/day)

oil is contained in the precook water for plants with essentially dry transport systems to the packing tables.

A comparison of waste loadings at plant SA2 with hiatorical data at the same plant before a conveyor was installed gives an indication of the reduction in water use and waste loadings which can be obtained using dry conveying. This comparison shows a reduction in water use by 63 percent, in BOD by 59 percent, and suspended solids by 77 percent. These percentages appear to present a larger reduction than could be obtained using the flume loadings observed at other plants. However, it does indicate that the use of dry conveyors can reduce the water use significantly and the waste loads to a lesser but substantial amount.

Wastewaters were generally discharged directly into the receiving waters at the plants sampled. Construction was underway at some plants to tie into municipal waste treatment facilities. Most plants utilized some form of screening to remove the solid waste materials prior to discharging. One plant observed, but not sampled due to lack of fish at the time, has installed a dissolved air flotation system for waste treatment (see Section VII). Tables 88 through 91 show summary statistics of the wastewater from each plant sampled or where data were available. Figure 50 presents a normalized sardine canning process plot for selected wastewater parameters. The historical data for plants SA2H, SA3 and SA4 were already reduced to time averages, hence, only one sample point is shown. Each of these time averages is reported to have come from three to five daily composite samples (22).

## Product Material Balance

Table 87 shows that the food product yield for the sardine canning process can vary from a low of 30 percent to a high of 60 percent. This wide range in yield is related to the size of fish being canned. Since the same size can is often utilized for various sizes of fish, more waste originates from the large fish, which have a higher percent of the head and tail removed.

The heads and tails that are removed are usually dry conveyed to trucks which transport the waste to reduction facilities. Some solid waste is also collected by lobster fishermen for bait. Scales, another by-product, are removed on the boats prior to storage, and are used for cosmetics, lacquers, and imitation pearls.

Product rates varied from a low of 26 kkg/day (29 tons/day) to a high of 35 kkg/day (39 tons/day) at the plants investigated.

## HERRING FILLETING WASTEWATER CHARACTERISTICS

Table 88 .  SARDINE CANNING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 6.51 | 1.43 | 4.17 | 8.33 |
| PROCESS TIME HR/DAY | 5.34 | -- | 3.30 | 8.00 |
| FLOW L/SEC | 3.94 | 0.656 | 2.68 | 5.52 |
| (GAL/MIN) | 62.6 | 10.4 | 42.5 | 87.7 |
| FLOW RATIO L/KKG | 2440 | 452 | 1630 | 3640 |
| (GAL/TON) | 586 | 108 | 391 | 872 |
| SETT. SOLIDS ML/L | 1.33 | 0.658 | 0.835 | 3.33 |
| RATIO L/KKG | 3.25 | 1.61 | 2.04 | 8.14 |
| SCR. SOLIDS MG/L | 148 | 133 | 43.9 | 327 |
| RATIO KG/KKG | 0.362 | 0.325 | 0.107 | 0.800 |
| SUSP. SOLIDS MG/L | 1590 | 656 | 640 | 3440 |
| RATIO KG/KKG | 3.88 | 1.60 | 1.56 | 8.42 |
| 5 DAY BOD MG/L | 4960 | 1240 | 2190 | 7190 |
| RATIO KG/KKG | 12.1 | 3.03 | 5.35 | 17.6 |
| COD MG/L | 6930 | 2310 | 2740 | 13400 |
| RATIO KG/KKG | 16.9 | 5.66 | 6.70 | 32.8 |
| GREASE & OIL MG/L | 1080 | 571 | 343 | 2780 |
| RATIO KG/KKG | 2.64 | 1.40 | 0.838 | 6.80 |
| ORGANIC-N MG/L | 406 | 109 | 137 | 629 |
| RATIO KG/KKG | 0.992 | 0.266 | 0.335 | 1.54 |
| AMMONIA-N MG/L | 13.6 | 2.71 | 7.21 | 20.0 |
| RATIO KG/KKG | 0.033 | 0.007 | 0.018 | 0.049 |
| PH | 6.40 | 0.138 | 6.17 | 6.83 |
| TEMP DEG C | 23.0 | 1.45 | 22.0 | 23.9 |

PLANT SA1
8 SAMPLES

## Table 89 . SARDINE CANNING PROCESS (DRY CONVEYING)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 4.07 | 0.760 | 3.20 | 4.60 |
| PROCESS TIME HR/DAY | 5.77 | — | 4.00 | 7.50 |
| FLOW L/SEC | 7.79 | 1.18 | 6.93 | 9.22 |
| (GAL/MIN) | 124 | 18.7 | 110 | 146 |
| FLOW RATIO L/KKG | 7590 | 1130 | 6240 | 8300 |
| (GAL/TON) | 1820 | 271 | 1500 | 1990 |
| SETT. SOLIDS ML/L | 2.53 | 1.85 | 0.392 | 4.09 |
| RATIO L/KKG | 19.2 | 14.1 | 2.98 | 31.1 |
| SCR. SOLIDS MG/L | 21.1 | — | — | — |
| RATIO KG/KKG | 0.160 | — | — | — |
| SUSP. SOLIDS MG/L | 264 | 97.9 | 155 | 355 |
| RATIO KG/KKG | 2.01 | 0.743 | 1.18 | 2.70 |
| 5 DAY BOD MG/L | 664 | 263 | 367 | 875 |
| RATIO KG/KKG | 5.04 | 1.99 | 2.79 | 6.65 |
| COD MG/L | 1060 | 362 | 654 | 1350 |
| RATIO KG/KKG | 8.08 | 2.75 | 4.96 | 10.3 |
| GREASE & OIL MG/L | 152 | 114 | 67.7 | 283 |
| RATIO KG/KKG | 1.15 | 0.866 | 0.514 | 2.15 |
| ORGANIC-N MG/L | 74.7 | 22.0 | 53.4 | 97.4 |
| RATIO KG/KKG | 0.567 | 0.167 | 0.405 | 0.740 |
| AMMONIA-N MG/L | 3.17 | 0.742 | 2.35 | 3.86 |
| RATIO KG/KKG | 0.024 | 0.006 | 0.018 | 0.029 |
| PH | 6.31 | 0.198 | 6.15 | 6.91 |
| TEMP DEG C | 18.5 | 0.292 | 18.3 | 18.8 |

PLANT SA2
3 SAMPLES

Table 90 . SARDINE CANNING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 4.61 | -- | -- | -- |
| PROCESS TIME HR/DAY | 8.00 | -- | -- | -- |
| FLOW L/SEC | 11.1 | -- | -- | -- |
| (GAL/MIN) | 176 | -- | -- | -- |
| FLOW RATIO L/KKG | 9550 | -- | -- | -- |
| (GAL/TON) | 2290 | -- | -- | -- |
| SETT. SOLIDS ML/L | -- | -- | -- | -- |
| RATIO L/KKG | -- | -- | -- | -- |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 1130 | -- | -- | -- |
| RATIO KG/KKG | 10.8 | -- | -- | -- |
| 5 DAY BOD MG/L | 1040 | -- | -- | -- |
| RATIO KG/KKG | 9.94 | -- | -- | -- |
| COD MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| GREASE & OIL MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| ORGANIC-N MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| AMMONIA-N MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| PH | -- | -- | -- | -- |
| TEMP DEG C | -- | -- | -- | -- |

PLANT SA3
1 SAMPLE

### Table 91 . SARDINE CANNING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 4.99 | -- | -- | -- |
| PROCESS TIME HR/DAY | 8.00 | -- | -- | -- |
| FLOW L/SEC | 13.5 | -- | -- | -- |
| (GAL/MIN) | 215 | -- | -- | -- |
| FLOW RATIO L/KKG | 10800 | -- | -- | -- |
| (GAL/TON) | 2580 | -- | -- | -- |
| SETT. SOLIDS ML/L | -- | -- | -- | -- |
| RATIO L/KKG | -- | -- | -- | -- |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 943 | -- | -- | -- |
| RATIO KG/KKG | 10.2 | -- | -- | -- |
| 5 DAY BOD MG/L | 1100 | -- | -- | -- |
| RATIO KG/KKG | 11.9 | -- | -- | -- |
| COD MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| GREASE & OIL MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| ORGANIC-N MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| AMMONIA-N MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| PH | -- | -- | -- | -- |
| TEMP DEG C | -- | -- | -- | -- |

PLANT SA4
1 SAMPLE

Two herring filleting plants were sampled during August, 1973, one in New England and one in Alaska. In addition, historical data were obtained from a plant operating in the maritime region of Canada (26). The sampling interval was during a period of peak production for New England, however, due to a poor harvest in 1973 and bad weather, the plants were operating on an intermittent basis. There were also breakdowns in the machinery, which was quite old and needed considerable maintenance and repair. The sampling interval in Alaska was during a slack season, therefore, only one day of operation was observed.

### Wastewater Material Balance

City water was used in both the New England and Alaskan plants monitored. Table 92 shows the sources of wastewater from a herring filleting process. The largest percentage of the total flow and waste load is produced by the filleting machines and the associated fluming. The flow from each filleting machine is only about 0.4 l/sec (6 gpm) however the fluming of product to and from the machine is much higher. The bailwater, when a fish pump unloading operation is used, constitutes a relatively large flow and waste loading. This could be reduced by using a dry unloading system.

Tables 93 through 95 summarize the wastewater characteristics of three herring filleting processes. The plants represented by codes HF1, HF2, and HF3 are in New England; New Brunswick, Canada; and Alaska, respectively. The waste loads are similar in terms of BOD and suspended solids. The flow ratio was much higher at HF3 because only a few fish were being processed and the flow through the filleting machine is independent of the rate that fish are being run through. The wastewater at the New England plant was screened and discharged to the receiving water, while the entire load was discharged in Alaska.

### Product Material Balance

The New England plant is relatively large and was observed to process an average of 78 kkg/day (86 tons/day) of raw fish when they were available. Each filleting machine operated at about 1.4 kkg/hr (1.5 tons/hr).

Table 92 shows percentages of food and by-product recovery for this process. The food product averages 42 to 45 percent but varies with the season and the type of filleting machine used. During the spring spawning season roe and milt are sometimes collected. This increases the food recovery by about three to five percent. The rest of the solid waste is either sent to reduction plants or discharged with the wastewater.

## CLAM PROCESS WASTEWATER CHARACTERISTICS

Table 92. Herring filleting process material balance

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) process water | 58% | 70% | 59% |
| b) bailwater | 37% | 27% | 38% |
| c) washdown | 5% | 3% | 3% |
| Total effluent average HF1 | 10,200 l/kkg | 34 kg/kkg | 23 kg/kkg |

Product Material Balance Summary

| End Product | % of Raw Product |
|---|---|
| Food products | 42 - 45% |
| By-product<br>a) heads, viscera (for reduction) | 55- 58% |

Average Production Rate, 78 kkg/day (86 tons/day)

## Table 93. HERRING FILLETING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 12.9 | 2.15 | 10.7 | 15.0 |
| PROCESS TIME HR/DAY | 6.67 | — | 3.50 | 9.00 |
| FLOW L/SEC | 33.5 | 0.769 | 32.6 | 34.1 |
| (GAL/MIN) | 532 | 12.2 | 518 | 542 |
| FLOW RATIO L/KKG | 10260 | 1050 | 9490 | 11400 |
| (GAL/TON) | 2460 | 253 | 2270 | 2740 |
| SETT. SOLIDS ML/L | 14.5 | 5.03 | 10.1 | 20.0 |
| RATIO L/KKG | 148 | 51.5 | 103 | 205 |
| SCR. SOLIDS MG/L | — | -- | — | -- |
| RATIO KG/KKG | -- | — | -- | — |
| SUSP. SOLIDS MG/L | 2210 | 439 | 1810 | 2680 |
| RATIO KG/KKG | 22.6 | 4.50 | 18.5 | 27.4 |
| 5 DAY BOD MG/L | 3330 | 775 | 2560 | 4100 |
| RATIO KG/KKG | 34.1 | 7.94 | 26.2 | 42.0 |
| COD MG/L | 6220 | 1050 | 5030 | 7010 |
| RATIO KG/KKG | 63.7 | 10.8 | 51.5 | 71.8 |
| GREASE & OIL MG/L | 597 | 95.0 | 495 | 683 |
| RATIO KG/KKG | 6.11 | 0.973 | 5.07 | 7.00 |
| ORGANIC-N MG/L | 434 | 80.6 | 353 | 514 |
| RATIO KG/KKG | 4.45 | 0.825 | 3.61 | 5.26 |
| AMMONIA-N MG/L | 21.3 | 2.40 | 18.6 | 23.3 |
| RATIO KG/KKG | 0.218 | 0.025 | 0.191 | 0.239 |
| PH | 6.91 | 0.076 | 6.82 | 6.97 |
| TEMP DEG C | 21.7 | 0.639 | 21.1 | 22.1 |

PLANT HF1
3 SAMPLES

## Table 94 . HERRING FILLETING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 4.72 | 1.22 | 3.63 | 6.04 |
| PROCESS TIME HR/DAY | 6.67 | -- | 4.00 | 8.00 |
| FLOW L/SEC | 5.57 | 0.536 | 5.03 | 6.10 |
| (GAL/MIN) | 88.4 | 8.52 | 79.8 | 96.9 |
| FLOW RATIO L/KKG | 4820 | 754 | 4020 | 5510 |
| (GAL/TON) | 1150 | 181 | 962 | 1320 |
| SETT. SOLIDS ML/L | -- | -- | -- | -- |
| RATIO L/KKG | -- | -- | -- | -- |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 4940 | 1190 | 3700 | 6080 |
| RATIO KG/KKG | 23.8 | 5.73 | 17.8 | 29.3 |
| 5 DAY BOD MG/L | 6280 | 3180 | 3520 | 9760 |
| RATIO KG/KKG | 30.2 | 15.3 | 16.9 | 47.0 |
| COD MG/L | 10000 | 3400 | 7230 | 13800 |
| RATIO KG/KKG | 48.4 | 16.4 | 34.8 | 66.6 |
| GREASE & OIL MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| ORGANIC-N MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| AMMONIA-N MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| PH | -- | -- | -- | -- |
| TEMP DEG C | -- | -- | -- | -- |

PLANT HF2
3 SAMPLES

## Table 95. HERRING FILLETING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.150 | -- | -- | -- |
| PROCESS TIME HR/DAY | 2.00 | -- | -- | -- |
| FLOW L/SEC | 1.01 | -- | -- | -- |
| (GAL/MIN) | 16.0 | -- | -- | -- |
| FLOW RATIO L/KKG | 26700 | -- | -- | -- |
| (GAL/TON) | 6400 | -- | -- | -- |
| SETT. SOLIDS ML/L | 2.00 | -- | -- | -- |
| RATIO L/KKG | 53.4 | -- | -- | -- |
| SCR. SOLIDS MG/L | 255 | -- | -- | -- |
| RATIO KG/KKG | 6.81 | -- | -- | -- |
| SUSP. SOLIDS MG/L | 632 | -- | -- | -- |
| RATIO KG/KKG | 16.9 | -- | -- | -- |
| 5 DAY BOD MG/L | 1220 | -- | -- | -- |
| RATIO KG/KKG | 32.6 | -- | -- | -- |
| COD MG/L | 2590 | -- | -- | -- |
| RATIO KG/KKG | 69.2 | -- | -- | -- |
| GREASE & OIL MG/L | 785 | -- | -- | -- |
| RATIO KG/KKG | 21.0 | -- | -- | -- |
| ORGANIC-N MG/L | 102 | -- | -- | -- |
| RATIO KG/KKG | 2.72 | -- | -- | -- |
| AMMONIA-N MG/L | 3.90 | -- | -- | -- |
| RATIO KG/KKG | 0.104 | -- | -- | -- |
| PH | 6.00 | -- | -- | -- |
| TEMP DEG C | 10.00 | -- | -- | -- |

PLANT HF3
1 SAMPLE

The wastewater characterization data from the clam processing industry are organized into mechanized shucking and/or canning operations and conventional hand shucking operations because of the different methods and waste loads involved. Figure 55 presents a normalized process plot of selected wastewater parameters for the conventional and mechanized clam processing plants sampled during this study.

## Mechanized Clam Process

Four mechanical clam shucking and/or canning plants were monitored during September and October, 1973, in the mid-Atlantic region. One conch shucking and canning process was also sampled in conjunction with the clam processes. Although clams are harvested all year, the plants operate on an intermittent basis since the clam dredging operation is highly dependent on the weather and roughness of the sea.

### Wastewater material balance

The water supply for the clam plants was from fresh water wells or municipal water supplies. Table 96 shows the wastewater balance for a typical clam canning operation and indicates that most of the flow and waste load is due to the washing operations. Typically, large amounts of water are used to wash the product at different stages in the process. One plant (FCL3) used a total of five drum washers, although two were more common. The washdown flow was also considerable at some plants and ranged from 22 percent to 45 percent at the plants observed.

Tables 97 and 98 summarize the characteristics of the wastewater from the mechanized clam plants utilized for the subcategory summary. The waste loads and flows are quite variable due to the various combinations of unit operations which are used. The plant represented by code FCL1 had a mechanized shucking operation but did not debelly and shipped the clams to another plant for further processing. Therefore, the flows and loads were much lower since the debellying and subsequent washing is a major unit operation in the clam process. Plants FCL2, FCL3, and CCL2 all produced a clam product with the bellies removed. Plants FCL2 and FCL3 removed the bellies mechanically while plant CCL2 used a manual debellying line. The flows and waste loads at plant FCL3 are higher due to the fact that considerable washing of the product is done and also because the clams are opened by steam cooking and the clam juice is condensed by evaporators. Code CCL1 represents a process which received preshucked clams from other plants and then washed and canned them. Since there was no shucking operation, this process had lower flows and waste loads. The tables indicate that the waste flows and loads from the mechanized clam operations are substantial and on the same order of magnitude as from the canned fish operations.

Table 96 . Surf clam canning process material balance

## Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) iron man | <1% | <1% | <1% |
| b) first washer | 35% | 31% | 52% |
| c) first skimming table | <1% | <1% | <1% |
| d) second washer | 16% | 24% | 25% |
| e) second skimming table | 15% | 32% | 15% |
| f) washdown | 33% | 13% | 8% |
| Total effluent average CCL2 | 21,000 l/kkg | 13 kg/kkg | 5.2 kg/kkg |

## Product Material Balance Summary

| End Products | % of Raw Product |
|---|---|
| Food products | 10 - 15% |
| By-products | |
| a) shell | 75 - 80% |
| Wastes | |
| a) belly | 7 - 10% |

Average Production Rate, 38 kkg/day (41 tons/day)

## Table 97 . SURF CLAM MEAT PROCESS (MECHANICALLY-SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 4.89 | 0.768 | 3.88 | 5.75 |
| PROCESS TIME HR/DAY | 7.50 | -- | -- | -- |
| FLOW L/SEC | 12.4 | 1.89 | 10.1 | 14.6 |
| (GAL/MIN) | 197 | 30.1 | 161 | 231 |
| FLOW RATIO L/KKG | 9570 | 1210 | 7900 | 10900 |
| (GAL/TON) | 2290 | 289 | 1890 | 2610 |
| SETT. SOLIDS ML/L | 3.29 | 1.48 | 2.11 | 5.55 |
| RATIO L/KKG | 31.5 | 14.2 | 20.2 | 53.1 |
| SCR. SOLIDS MG/L | 201 | 190 | 78.1 | 486 |
| RATIO KG/KKG | 1.92 | 1.82 | 0.747 | 4.65 |
| SUSP. SOLIDS MG/L | 297 | 164 | 157 | 549 |
| RATIO KG/KKG | 2.84 | 1.56 | 1.50 | 5.26 |
| 5 DAY BOD MG/L | 1280 | 256 | 993 | 1590 |
| RATIO KG/KKG | 12.2 | 2.45 | 9.50 | 15.2 |
| COD MG/L | 1460 | 425 | 1050 | 2100 |
| RATIO KG/KKG | 14.0 | 4.07 | 10.0 | 20.1 |
| GREASE & OIL MG/L | 24.5 | 7.09 | 15.8 | 32.3 |
| RATIO KG/KKG | 0.235 | 0.068 | 0.151 | 0.309 |
| ORGANIC-N MG/L | 167 | 44.7 | 124 | 224 |
| RATIO KG/KKG | 1.60 | 0.428 | 1.18 | 2.14 |
| AMMONIA-N MG/L | 6.16 | 1.13 | 5.25 | 7.06 |
| RATIO KG/KKG | 0.059 | 0.011 | 0.050 | 0.068 |
| PH | 7.04 | 0.060 | 6.97 | 7.14 |
| TEMP DEG C | 22.5 | 1.33 | 21.6 | 23.9 |

PLANT FC12
4 SAMPLES

Table 98 . SURF CLAM MEAT PROCESS
(MECHANICALLY-SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 12.0 | -- | -- | -- |
| PROCESS TIME HR/DAY | 7.10 | -- | 6.50 | 7.50 |
| FLOW L/SEC | 122 | 14.8 | 97.0 | 134 |
| (GAL/MIN) | 1940 | 235 | 1540 | 2130 |
| FLOW RATIO L/KKG | 39900 | 4960 | 31000 | 44300 |
| (GAL/TON) | 9570 | 1190 | 7430 | 10600 |
| SETT. SOLIDS ML/L | 4.09 | 1.02 | 2.32 | 4.94 |
| RATIO L/KKG | 163 | 40.6 | 92.6 | 197 |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 356 | 127 | 179 | 534 |
| RATIO KG/KKG | 14.2 | 5.06 | 7.13 | 21.3 |
| 5 DAY BOD MG/L | 719 | 215 | 341 | 980 |
| RATIO KG/KKG | 28.7 | 8.57 | 13.6 | 39.1 |
| COD MG/L | 1380 | 772 | 633 | 2740 |
| RATIO KG/KKG | 55.0 | 30.8 | 25.3 | 109 |
| GREASE & OIL MG/L | 22.7 | 6.93 | 13.0 | 33.9 |
| RATIO KG/KKG | 0.905 | 0.277 | 0.517 | 1.35 |
| ORGANIC-N MG/L | 89.8 | 29.6 | 53.5 | 135 |
| RATIO KG/KKG | 3.59 | 1.18 | 2.14 | 5.38 |
| AMMONIA-N MG/L | 3.81 | 1.36 | 2.28 | 6.09 |
| RATIO KG/KKG | 0.152 | 0.054 | 0.091 | 0.243 |
| PH P | 6.10 | 0.238 | 5.78 | 6.74 |
| TEMP DEG C | 36.4 | 3.31 | 33.9 | 38.5 |

PLANT FCL3
5 SAMPLES

The wastewaters are commonly discharged to receiving waters; however, some discharged to municipal systems and one plant located a few miles inland was using a spray irrigation disposal system. Some plants use grit chambers to remove sand and shell particles and one plant (FCL3) screened their effluent through a tangential screen before discharge.

## Product material balance

The production rates at the plants monitored were variable and depended to a large degree on the combination of unit operations employed. The plant which shucked but did not debelly (FCL1), handled a large volume of clams, averaging 147 kkg/day (162 tons/day). The ratio between the weight of clams in the shell to clams before debellying is about four to one. The average production at plants which shucked and debellied the clams was about 50 kkg/day (55 tons/day). The final food product without the bellies is about 10 to 15 percent of the weight in the shell. The clam bellies are sometimes used for bait or animal food but are often discharged to the receiving waters or ground up and discharged to the municipal sewer system. Clam shells are generally used for fill or road beds but are sometimes barged back to the clam beds.

## Conventional Clam Process

Three conventional hand shucking clam processes were monitored during September, 1973, in the mid-Atlantic region. The plants operate all year on an intermittent basis. The conventional plants are generally smaller than the mechanized plants.

## Wastewater material balance

The hand shucked clam plants are usually located in rural communities or areas and obtain water from domestic supplies or fresh water wells. Table 99 shows that most of the waste flow and loads come from the washing operations after shucking and debellying.

It can be seen that the flows and loads are much lower, except for 5-day BOD versus suspended solids, from the hand shucking operation than from the mechanized operations. The suspended solids parameter is hard to sample accurately, especially during washdowns, since the concentration of fine sand fluctuates greatly at the beginning of the period. Tables 100 through 102 summarize the characteristics of the wastewater from each of the three plants monitored. The wastewater is generally discharged to the receiving water with no treatment.

## Product material balance

Table 99. Hand shucked clam process material balance.

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) first and second washers | 83-92 | 65-97 | 10-96 |
| b) washdown | 8-17 | 3-34 | 4-89 |
| Total effluent average | 5100 l/kkg | 5.3 kg/kkg | 12 kg/kkg |

Average production rate: 20 kkg/day (22 tons/day).

## Table 100 . CLAM FRESH/FROZEN PROCESS (HAND-SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 4.08 | -- | -- | -- |
| PROCESS TIME HR/DAY | 6.00 | -- | -- | -- |
| FLOW L/SEC | 7.64 | -- | -- | -- |
| (GAL/MIN) | 121 | -- | -- | -- |
| FLOW RATIO L/KKG | 7440 | -- | -- | -- |
| (GAL/TON) | 1780 | -- | -- | -- |
| SETT. SOLIDS ML/L | 8.04 | -- | -- | -- |
| RATIO L/KKG | 59.8 | -- | -- | -- |
| SCR. SOLIDS MG/L | 547 | -- | -- | -- |
| RATIO KG/KKG | 4.06 | -- | -- | -- |
| SUSP. SOLIDS MG/L | 581 | -- | -- | -- |
| RATIO KG/KKG | 4.32 | -- | -- | -- |
| 5 DAY BOD MG/L | 843 | -- | -- | -- |
| RATIO KG/KKG | 6.27 | -- | -- | -- |
| COD MG/L | 1410 | -- | -- | -- |
| RATIO KG/KKG | 10.5 | -- | -- | -- |
| GREASE & OIL MG/L | 37.4 | -- | -- | -- |
| RATIO KG/KKG | 0.278 | -- | -- | -- |
| ORGANIC-N MG/L | 138 | -- | -- | -- |
| RATIO KG/KKG | 1.03 | -- | -- | -- |
| AMMONIA-N MG/L | 5.18 | -- | -- | -- |
| RATIO KG/KKG | 0.039 | -- | -- | -- |
| PH | 6.91 | -- | -- | -- |
| TEMP DEG C | 19.5 | -- | -- | -- |

PLANT HCL'
1 SAMPLE

## Table 101. CLAM FRESH/FROZEN PROCESS (HAND-SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 6.53 | 1.21 | 4.78 | 7.48 |
| PROCESS TIME HR/DAY | 5.50 | -- | 2.50 | 8.00 |
| FLOW L/SEC | 3.59 | 0.657 | 2.65 | 4.10 |
| (GAL/MIN) | 57.0 | 10.4 | 42.0 | 65.0 |
| FLOW RATIO L/KKG | 2280 | 771 | 1480 | 3330 |
| (GAL/TON) | 546 | 185 | 355 | 799 |
| SETT. SOLIDS ML/L | 10.0 | 6.57 | 1.73 | 15.9 |
| RATIO L/KKG | 22.9 | 15.0 | 3.94 | 36.3 |
| SCR. SOLIDS MG/L | 2460 | 1920 | 649 | 5150 |
| RATIO KG/KKG | 5.60 | 4.37 | 1.48 | 11.7 |
| SUSP. SOLIDS MG/L | 6660 | 3100 | 3990 | 10600 |
| RATIO KG/KKG | 15.2 | 7.06 | 9.09 | 24.2 |
| 5 DAY BOD MG/L | 2680 | 1070 | 1670 | 4180 |
| RATIO KG/KKG | 6.11 | 2.43 | 3.80 | 9.52 |
| COD MG/L | 4060 | 1530 | 2600 | 6210 |
| RATIO KG/KKG | 9.24 | 3.49 | 5.92 | 14.1 |
| GREASE & OIL MG/L | 52.2 | 26.8 | 25.7 | 80.6 |
| RATIO KG/KKG | 0.119 | 0.061 | 0.059 | 0.184 |
| ORGANIC-N MG/L | 421 | 164 | 258 | 648 |
| RATIO KG/KKG | 0.960 | 0.374 | 0.589 | 1.48 |
| AMMONIA-N MG/L | 8.00 | 3.41 | 5.60 | 12.9 |
| RATIO KG/KKG | 0.018 | 0.008 | 0.013 | 0.029 |
| PH | 7.04 | 0.111 | 6.93 | 7.20 |
| TEMP DEG C | 18.6 | 1.10 | 17.8 | 19.8 |

PLANT HCL2
4 SAMPLES

Table 102 CLAM FRESH/FROZEN PROCESS
(HAND-SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 3.43 | -- | -- | -- |
| PROCESS TIME HR/DAY | 2.30 | -- | -- | -- |
| FLOW L/SEC | 4.85 | -- | -- | -- |
| (GAL/MIN) | 77.1 | -- | -- | -- |
| FLOW RATIO L/KKG | 5610 | -- | -- | -- |
| (GAL/TON) | 1350 | -- | -- | -- |
| SETT. SOLIDS ML/L | 3.01 | -- | -- | -- |
| RATIO L/KKG | 16.9 | -- | -- | -- |
| SCR. SOLIDS MG/L | 273 | -- | -- | -- |
| RATIO KG/KKG | 1.53 | -- | -- | -- |
| SUSP. SOLIDS MG/L | 2910 | -- | -- | -- |
| RATIO KG/KKG | 16.4 | -- | -- | -- |
| 5 DAY BOD MG/L | 632 | -- | -- | -- |
| RATIO KG/KKG | 3.55 | -- | -- | -- |
| COD MG/L | 958 | -- | -- | -- |
| RATIO KG/KKG | 5.38 | -- | -- | -- |
| GREASE & OIL MG/L | 16.4 | -- | -- | -- |
| RATIO KG/KKG | 0.092 | -- | -- | -- |
| ORGANIC-N MG/L | 102 | -- | -- | -- |
| RATIO KG/KKG | 0.574 | -- | -- | -- |
| AMMONIA-N MG/L | 3.51 | -- | -- | -- |
| RATIO KG/KKG | 0.020 | -- | -- | -- |
| PH | 7.02 | -- | -- | -- |
| TEMP DEG C | -- | -- | -- | -- |

PLANT HCL3
1 SAMPLE

The production rates at the three plants sampled averaged about 20 kkg/day (22 tons/day) which was about half the rate of the mechanized plants and ranged from 7 kkg/day (8 tons/day) to 33 kkg/day (36 tons/day). The yield of food product from the hand shucked plants is similar to the mechanized plants. The final product is shipped to other plants for further processing into canned clams or chowder.

## OYSTER PROCESS WASTEWATER CHARACTERISTICS

The wastewater characterization data from the oyster processing industry is organized into mechanical steamed or canned operations and conventional hand shucking operations because of the different methods and waste loads involved. Figure 58 presents a normalized process plot of selected wastewater parameters for the fresh/frozen, steamed, or canned oyster processing plants sampled during this study.

### Steamed or Canned Oysters

Two steamed oyster processes in the mid-Atlantic region and two canned oyster processes in the Northwest were monitored during September and October, 1973. The two steamed oyster processes and one canned oyster process were similar, in that shucking of the oysters was facilitated by steaming the oyster to loosen the meat from the shell. The other canned oyster process used pieces of meat from hand shucking operations and then canned them as oyster stew. There was some difficulty encountered sampling one of the steamed oyster plants (SO2) becuase of the numerous discharge points.

Historical Gulf Coast Oyster canning data, plant SOU, was obtained from the American Shrimp Canners Association. The Gulf Coast process includes an external wash of the raw oyster, steaming in the shell, mechanical shucking, and brine flotation for separation of the oysters from the shells.

### Wastewater material balance

The two plants on the East Coast were located in small communities and obtained water from domestic supplies. The plants on the West Coast were located in more rural areas and obtained their water from wells.

Table 103 shows the wastewater balance for a typical steamed oyster process. It is observed that a large portion of the flow and load is caused by the washdown at these plants. The largest flow comes from the culler and shocker which is used to clean and partially open the shell before steam cooking; however, the BOD load is relatively small.

## Table 103 · Steamed oyster process material balance

### Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) belt washer | 11% | 10% | 63% |
| b) shocker | 43% | 9% | 26% |
| c) shucker | 15% | 11% | 1% |
| d) blow tanks | 7% | 6% | <1% |
| e) washdown | 23% | 64% | 10% |
| Total effluent average<br>SO2 | 66.500 l/kkg | 30 kg/kkg | 137 kg/kkg |

Average Production Rate, 6.8 kkg/day (7.5 tons/day)
(production for the oyster processes is measured in terms of final product)

Tables 104 through 107 summarize the characteristics of the wastewater from the steamed or canned oyster plants which are included in the subcategory summary. Codes S01 and S02 represent the two East Coast steamed oyster plants. The waste loads appear to be higher at S01. This could be caused by the higher water use or sampling problems caused by the numerous outfalls at S02. The results from plant S01 are considered to be the most accurate. Code C01 represents a canned oyster process on the West Coast which is similar to the East Coast operation except that the oyster meat is removed from the shell manually after steaming and is then canned and retorted. The waste load, in terms of BOD, is about the same or a little higher than from the East Coast operations. The suspended solids is much lower at the West Coast plant as the shells are typically washed before they enter the plant. Code C02 represents an oyster stew process on the West Coast. This process uses pieces of broken oyster from hand shucking operations which are not desirable for the fresh/frozen market. The wastes are lower since the process does not include a shucking operation. Wastewater from the oyster plants are typically discharged directly to the receiving water. Table 107 summarizes the characteristics of the waste water from the Gulf Coast oyster canning operation.

### Product material balance

Production rates at the East Coast steamed oyster plants averaged 7.0 kkg/day (7.7 tons/day) of finished product. Oyster production is usually measured in terms of final product since the ratio between raw and final product is quite variable due to loose or empty shells. The production rate at the West Coast oyster canning plants averaged 1.4 kkg/day (1.5 tons/day) for the canning operation and 3.2 kkg/day (3.5 tons/day) for the stew operation. The stew operation, however, is usually done only once a week after the oyster pieces have accumulated to a sufficient amount.

### Hand Shucked Oysters

Six hand shucked oyster processes in the mid-Atlantic region were monitored during September and October, 1973 and four hand shucked oyster processes in the Northwest were monitored during October and November, 1973. In general, there was no problem with the availability of product in either region during this period. Processes of all size ranges, from those employing a few shuckers to those with a capacity of over 100 shuckers were sampled. Regardless of size, the processes are similar and relatively easy to sample.

### Wastewater material balance

Table 104. Hand shucked oyster process material balance

East Coast

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) blow tank | 71 - 94% | 81 - 94% | 11 - 58% |
| b) washdown | 6 - 29% | 6 - 19% | 42 - 89% |
| Total effluent average | 37.000 l/kkg | 14 kg/kkg | 11 kg/kkg |

West Coast

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) blow tank | 45 - 68% | 83 - 95% | 24 - 75% |
| b) washdown | 32 - 55% | 5 - 17% | 25 - 76% |
| Total effluent average | 41.000 l/kkg | 25 kg/kkg | 26 kg/kkg |

(Production for the oyster processes is measured in terms of final product)

## Table 105 . OYSTER STEAM PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.956 | 0.480 | 0.418 | 1.60 |
| PROCESS TIME HR/DAY | 7.18 | -- | 5.50 | 9.30 |
| FLOW L/SEC | 15.4 | 1.86 | 11.9 | 17.3 |
| (GAL/MIN) | 244 | 29.5 | 190 | 275 |
| FLOW RATIO L/KKG | 85400 | 29600 | 48500 | 124000 |
| (GAL/TON) | 20500 | 7100 | 11600 | 29800 |
| SETT. SOLIDS ML/L | 7.14 | 2.57 | 3.29 | 10.4 |
| RATIO L/KKG | 610 | 219 | 281 | 891 |
| SCR. SOLIDS MG/L | 2460 | 2260 | 420 | 5620 |
| RATIO KG/KKG | 210 | 193 | 35.8 | 480 |
| SUSP. SOLIDS MG/L | 1570 | 1180 | 714 | 3380 |
| RATIO KG/KKG | 134 | 101 | 61.0 | 289 |
| 5 DAY BOD MG/L | 546 | 401 | 200 | 919 |
| RATIO KG/KKG | 46.7 | 34.3 | 17.0 | 78.5 |
| COD MG/L | 903 | 593 | 355 | 1640 |
| RATIO KG/KKG | 77.2 | 50.7 | 30.3 | 140 |
| GREASE & OIL MG/L | 16.9 | 9.32 | 6.70 | 31.8 |
| RATIO KG/KKG | 1.44 | 0.797 | 0.572 | 2.72 |
| ORGANIC-N MG/L | 54.7 | 40.1 | 17.4 | 101 |
| RATIO KG/KKG | 4.67 | 3.42 | 1.49 | 8.64 |
| AMMONIA-N MG/L | 2.54 | 1.17 | 0.984 | 4.06 |
| RATIO KG/KKG | 0.217 | 0.100 | 0.084 | 0.347 |
| PH | 7.07 | 0.116 | 6.94 | 7.35 |
| TEMP DEG C | 20.1 | 1.74 | 18.2 | 21.6 |

PLANT S01
5 SAMPLES

## Table 106. OYSTER STEAM PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.920 | 0.125 | 0.675 | 1.04 |
| PROCESS TIME HR/DAY | 8.19 | -- | 8.00 | 8.80 |
| FLOW L/SEC | 13.9 | 0.581 | 13.4 | 15.0 |
| (GAL/MIN) | 220 | 9.22 | 213 | 239 |
| FLOW RATIO L/KKG | 66500 | 9610 | 58400 | 85600 |
| (GAL/TON) | 15900 | 2300 | 14000 | 20500 |
| SETT. SOLIDS ML/L | 11.7 | 4.05 | 7.92 | 18.8 |
| RATIO L/KKG | 781 | 269 | 527 | 1250 |
| SCR. SOLIDS MG/L | 2910 | 637 | 2040 | 4070 |
| RATIO KG/KKG | 193 | 42.4 | 136 | 271 |
| SUSP. SOLIDS MG/L | 2060 | 860 | 835 | 3640 |
| RATIO KG/KKG | 137 | 57.2 | 55.6 | 242 |
| 5 DAY BOD MG/L | 448 | 59.7 | 392 | 570 |
| RATIO KG/KKG | 29.8 | 3.97 | 26.1 | 37.9 |
| COD MG/L | 926 | 172 | 688 | 1260 |
| RATIO KG/KKG | 61.6 | 11.4 | 45.8 | 83.9 |
| GREASE & OIL MG/L | 19.0 | 5.41 | 13.9 | 29.9 |
| RATIO KG/KKG | 1.26 | 0.360 | 0.928 | 1.99 |
| ORGANIC-N MG/L | 52.8 | 9.93 | 40.0 | 71.1 |
| RATIO KG/KKG | 3.51 | 0.661 | 2.66 | 4.73 |
| AMMONIA-N MG/L | 2.93 | 0.875 | 2.15 | 4.29 |
| RATIO KG/KKG | 0.195 | 0.058 | 0.143 | 0.285 |
| PH | 7.07 | 0.087 | 6.92 | 7.16 |
| TEMP DEG C | 19.8 | 0.786 | 18.8 | 20.8 |

PLANT SO2
7 SAMPLES

## TABLE 107
## OYSTER STEAM PROCESS

| Parameter | | Mean |
|---|---|---|
| Production | tons/hr | 0.26 |
| Flow | l/sec | 10.6 |
| | gal/min | 168 |
| Flow Ratio | l/kkg | 167,000 |
| | gal/ton | 39,990 |
| Total Susp. Solids | mg/l | 656 |
| | kg/kkg | 203 |
| 5 day BOD | mg/l | 693 |
| | kg/kkg | 165 |
| COD | mg/l | 1090 |
| | kg/kkg | 204 |
| Grease & Oil | mg/l | 9 |
| | kg/kkg | 1.8 |
| pH | | 7.2 |

(Plant SOV)
3 samples

The plants on the East Coast obtained water either from domestic supplies or from wells, while the plants on the West Coast obtained their water from wells.

Table 104 shows the wastewater balance for typical East and West Coast hand shucked oyster processes. It can be seen that the two main sources of water are the blow tanks and the washdowns. The blow tanks, which are used to wash and add water to the product, are the major sources of wastewater and BOD loads. The washdowns can be a major source of suspended solids due to the fine pieces of sand which are on or in the oyster shells.

Tables 108 through 116 summarize the characteristics of the waste loads from the hand shucked oyster plants included in the subcategory summary. Codes HS01 through HS06 represent East Coast plants while codes HS08 through HS11 represent West Coast plants.

In general, the wastewater loads were higher at the West Coast plants than the East Coast plants. The reason for this appears to be due to the difference in the type of oysters processed and the flows used. The West Coast plants typically use more water in washing the product than the Eash Coast plants. The West Coast oyster is also larger and tends to break easier during handling. One plant on the East Coast (HS05) breaded the oysters after shucking. This operation was found to contribute about 50 percent of the BOD load at that plant; however, the overall load was about average due to good water conservation practices. The wastewater from hand shucked oyster processes is typically discharged directly to the receiving water.

### Product material balance

The average production rate of the East Coast plants sampled was 800 kg/day (1800 lbs/day) of final product; however, there was a wide range of from about 250 kg/day (540 lbs/day) to 2100 kg/day (4500 lbs/day). The West Coast plants observed had higher production rates averaging about 1100 kg/day (2500 lbs/day). All oyster production volumes or rates are in terms of final product, since the input shell weight to final product weight is too variable for accurate measurements.

## Scallop Freezing Process Wastewater Characteristics

Two scallop freezing processes were monitored in Alaska during July and August of 1973. Although this was about the middle of an average scallop harvest season, some difficulty was experienced in obtaining samples due to intermittent processing.

### Wastewater material balance

Both plants sampled used chlorinated municipal water sources, derived from reservoirs and deep wells. The only wastewater produced was in the washing operation; however, each plant sampled had a different method. Plant SP1 used a two stage continuous flow washing system in which a large volume of fresh water was used. Plant SP2 used a non-flowing brine tank which was dumped approximately every eight hours.

Tables 117 and 118 summarize the wastewater characteristics for each plant sampled. It can be seen that, although the flow is much higher for SP1, the BOD loads were similar for the two processes and relatively low compared to other seafood processing operations.

The effluent was discharged to the receiving water at one plant and to the municipal sewer system at the other plant.

### Product material balance

Production rates for the two plants were similar, averaging about 9 kkg/day (10 tons/day) of finished product. Production rates for the scallops were recorded in terms of finished product since they are shelled and eviscerated at sea. The yield is nearly 100 percent since the only wastes produced are small scallop pieces not suitable for freezing, solid waste removed during inspection, and small amounts of dissolved organic matter.

## FRESH/FROZEN ABALONE PROCESS WASTEWATER CHARACTERISTICS

Three abalone processors in Southern California were monitored during the month of October, 1973, which is a period of average production. All of the plants were located in metropolitan areas, utilized domestic water supplies, and discharged the effluent to the municipal treatment plant.

### Wastewater Material Balance

Table 119 shows that the primary source of wastewater is from the processing area and consists of various small flows used to keep the area clean. These small flows may be either continuous or intermittent at the discretion of the plant personnel. The flat surfaces of the processing table and the slicing machines are periodically cleansed to facilitate handling as well as to rinse away accumulated wastes. Washwater that is used to cleanse the foot muscle prior to trimming was handled differently in each of the three plants sampled. The largest plant, AB1, utilized recirculated washwater which was dumped twice a day. Plant AB2 used a system which recirculated the washwater during a single wash cycle and then discharged it, and plant AB3 used a continuous flow of water through the washing mechanism during each wash cycle.

### Table 108. OYSTER-FRESH/FROZEN PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.282 | 0.090 | 0.213 | 0.383 |
| PROCESS TIME HR/DAY | 7.33 | -- | 6.00 | 8.00 |
| FLOW L/SEC | 2.29 | 0.596 | 1.66 | 2.85 |
| (GAL/MIN) | 36.4 | 9.47 | 26.4 | 45.2 |
| FLOW RATIO L/KKG | 36600 | 3990 | 34200 | 41200 |
| (GAL/TON) | 8780 | 956 | 8200 | 9890 |
| SETT. SOLIDS ML/L | 1.77 | -- | -- | -- |
| RATIO L/KKG | 64.8 | -- | -- | -- |
| SCR. SOLIDS MG/L | 222 | 3.95 | 218 | 225 |
| RATIO KG/KKG | 8.14 | 0.145 | 7.97 | 8.25 |
| SUSP. SOLIDS MG/L | 304 | 20.3 | 286 | 326 |
| RATIO KG/KKG | 11.2 | 0.746 | 10.5 | 12.0 |
| 5 DAY BOD MG/L | 302 | 85.2 | 243 | 399 |
| RATIO KG/KKG | 11.1 | 3.12 | 8.89 | 14.6 |
| COD MG/L | 569 | 120 | 496 | 708 |
| RATIO KG/KKG | 20.9 | 4.40 | 18.2 | 25.9 |
| GREASE & OIL MG/L | 15.1 | 3.97 | 10.5 | 17.7 |
| RATIO KG/KKG | 0.552 | 0.145 | 0.385 | 0.648 |
| ORGANIC-N MG/L | 52.9 | 10.4 | 45.2 | 64.7 |
| RATIO KG/KKG | 1.94 | 0.381 | 1.66 | 2.37 |
| AMMONIA-N MG/L | 2.63 | 0.152 | 2.47 | 2.77 |
| RATIO KG/KKG | 0.096 | 0.006 | 0.090 | 0.102 |
| PH | 7.07 | 0.042 | 7.05 | 7.13 |
| TEMP DEG C | 15.6 | -- | -- | -- |

PLANT HSO2
3 SAMPLES

## Table 109. OYSTER FRESH/FROZEN PROCESS (HAND-SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.139 | 0.017 | 0.125 | 0.163 |
| PROCESS TIME HR/DAY | 5.70 | -- | 4.30 | 8.00 |
| FLOW L/SEC | 0.831 | 0.219 | 0.650 | 1.14 |
| (GAL/MIN) | 13.2 | 3.47 | 10.3 | 18.1 |
| FLOW RATIO L/KKG | 24500 | 3800 | 21000 | 29800 |
| (GAL/TON) | 5870 | 911 | 5040 | 7140 |
| SETT. SOLIDS ML/L | 2.82 | 0.193 | 2.65 | 3.03 |
| RATIO L/KKG | 69.1 | 4.71 | 64.8 | 74.2 |
| SCR. SOLIDS MG/L | 319 | 3.07 | 317 | 323 |
| RATIO KG/KKG | 7.81 | 0.075 | 7.77 | 7.90 |
| SUSP. SOLIDS MG/L | 437 | 20.9 | 414 | 464 |
| RATIO KG/KKG | 10.7 | 0.511 | 10.1 | 11.4 |
| 5 DAY BOD MG/L | 346 | 66.2 | 261 | 404 |
| RATIO KG/KKG | 8.46 | 1.62 | 6.39 | 9.89 |
| COD MG/L | 699 | 166 | 472 | 856 |
| RATIO KG/KKG | 17.1 | 4.05 | 11.6 | 21.0 |
| GREASE & OIL MG/L | 20.0 | 3.80 | 14.4 | 22.6 |
| RATIO KG/KKG | 0.490 | 0.093 | 0.353 | 0.554 |
| ORGANIC-N MG/L | 63.8 | 14.4 | 43.9 | 77.4 |
| RATIO KG/KKG | 1.56 | 0.353 | 1.07 | 1.90 |
| AMMONIA-N MG/L | 3.28 | 0.452 | 2.85 | 3.92 |
| RATIO KG/KKG | 0.080 | 0.011 | 0.070 | 0.096 |
| PH | 7.10 | 0.076 | 7.01 | 7.17 |
| TEMP DEG C | 15.6 | -- | -- | -- |

PLANT HS03
4 SAMPLES

## Table 110 OYSTER FRESH/FROZEN PROCESS (HAND-SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.109 | 0.029 | 0.091 | 0.160 |
| PROCESS TIME HR/DAY | 5.40 | -- | 5.00 | 6.50 |
| FLOW L/SEC | 3.12 | 1.28 | 1.35 | 4.88 |
| (GAL/MIN) | 49.6 | 20.3 | 21.4 | 77.4 |
| FLOW RATIO L/KKG | 112000 | 32900 | 56800 | 139000 |
| (GAL/TON) | 26800 | 7880 | 13600 | 33300 |
| SETT. SOLIDS ML/L | 0.867 | -- | -- | -- |
| RATIO L/KKG | 96.8 | -- | -- | -- |
| SCR. SOLIDS MG/L | 87.5 | 7.98 | 77.1 | 98.3 |
| RATIO KG/KKG | 9.77 | 0.891 | 8.60 | 11.0 |
| SUSP. SOLIDS MG/L | 203 | 126 | 139 | 427 |
| RATIO KG/KKG | 22.7 | 14.0 | 15.5 | 47.7 |
| 5 DAY BOD MG/L | 258 | 51.4 | 187 | 330 |
| RATIO KG/KKG | 28.8 | 5.74 | 20.9 | 36.8 |
| COD MG/L | 572 | 73.0 | 474 | 670 |
| RATIO KG/KKG | 63.8 | 8.14 | 52.9 | 74.7 |
| GREASE & OIL MG/L | 15.4 | 5.11 | 7.26 | 20.6 |
| RATIO KG/KKG | 1.72 | 0.571 | 0.810 | 2.30 |
| ORGANIC-N MG/L | 51.6 | 8.21 | 42.3 | 60.7 |
| RATIO KG/KKG | 5.76 | 0.916 | 4.72 | 6.78 |
| AMMONIA-N MG/L | 1.98 | 0.817 | 1.02 | 3.18 |
| RATIO KG/KKG | 0.221 | 0.091 | 0.114 | 0.355 |
| PH | 7.10 | 0.112 | 7.00 | 7.39 |
| TEMP DEG C | 19.8 | 0.795 | 18.7 | 20.7 |

PLANT HS04
5 SAMPLES

Table 111.. OYSTER FRESH/FROZEN PROCESS
(HAND-SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.147 | 0.011 | 0.133 | 0.160 |
| PROCESS TIME HR/DAY | 7.47 | -- | 7.30 | 7.50 |
| FLOW L/SEC | 1.31 | 0.226 | 0.854 | 1.56 |
| (GAL/MIN) | 20.8 | 3.62 | 13.6 | 24.8 |
| FLOW RATIO L/KKG | 36900 | 6840 | 24000 | 46900 |
| (GAL/TON) | 8850 | 1640 | 5760 | 11200 |
| SETT. SOLIDS ML/L | 1.77 | -- | -- | -- |
| RATIO L/KKG | 65.5 | -- | -- | -- |
| SCR. SOLIDS MG/L | 217 | 7.71 | 209 | 224 |
| RATIO KG/KKG | 8.01 | 0.284 | 7.71 | 8.28 |
| SUSP. SOLIDS MG/L | 308 | 15.8 | 293 | 332 |
| RATIO KG/KKG | 11.3 | 0.584 | 10.8 | 12.2 |
| 5 DAY BOD MG/L | 372 | 91.2 | 263 | 511 |
| RATIO KG/KKG | 13.7 | 3.36 | 9.72 | 18.9 |
| COD MG/L | 680 | 182 | 459 | 924 |
| RATIO KG/KKG | 25.1 | 6.73 | 17.0 | 34.1 |
| GREASE & OIL MG/L | 16.4 | 2.77 | 11.9 | 19.4 |
| RATIO KG/KKG | 0.605 | 0.102 | 0.439 | 0.715 |
| ORGANIC-N MG/L | 42.0 | 15.4 | 22.8 | 66.8 |
| RATIO KG/KKG | 1.55 | 0.568 | 0.843 | 2.46 |
| AMMONIA-N MG/L | 2.36 | 0.323 | 1.89 | 2.80 |
| RATIO KG/KKG | 0.087 | 0.012 | 0.070 | 0.103 |
| PH | 7.10 | 0.074 | 7.00 | 7.29 |
| TEMP DEG C | 17.7 | 0.799 | 16.9 | 18.6 |

PLANT HS06
7 SAMPLES

## TABLE 112
## OYSTER FRESH/FROZEN PROCESS
## (HAND-SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.055 | 0.010 | 0.040 | 0.067 |
| PROCESS TIME HR/DAY | 5.14 | -- | 4.00 | 6.00 |
| FLOW L/SEC | 0.909 | 0.186 | 0.730 | 1.16 |
| (GAL/MIN) | 14.4 | 2.95 | 11.6 | 18.3 |
| FLOW RATIO L/KKG | 67800 | 8160 | 52300 | 75600 |
| (GAL/TON) | 16300 | 1960 | 12500 | 18100 |
| SETT. SOLIDS ML/L | 1.94 | 0.804 | 1.34 | 2.53 |
| RATIO L/KKG | 131 | 54.5 | 91.2 | 172 |
| SCR. SOLIDS MG/L | 317 | 107 | 202 | 534 |
| RATIO KG/KKG | 21.5 | 7.23 | 13.7 | 36.2 |
| SUSP. SOLIDS MG/L | 315 | 17.5 | 291 | 337 |
| RATIO KG/KKG | 21.3 | 1.19 | 19.8 | 22.8 |
| 5 DAY BOD MG/L | 263 | 90.2 | 159 | 424 |
| RATIO KG/KKG | 17.9 | 6.12 | 10.8 | 28.8 |
| COD MG/L | 488 | 172 | 280 | 789 |
| RATIO KG/KKG | 33.1 | 11.7 | 19.0 | 53.5 |
| GREASE & OIL MG/L | 13.7 | 3.66 | 9.01 | 20.8 |
| RATIO KG/KKG | 0.928 | 0.249 | 0.612 | 1.41 |
| ORGANIC-N MG/L | 37.2 | 15.1 | 22.1 | 63.0 |
| RATIO KG/KKG | 2.52 | 1.02 | 1.50 | 4.27 |
| AMMONIA-N MG/L | 2.41 | 0.563 | 1.78 | 3.26 |
| RATIO KG/KKG | 0.163 | 0.038 | 0.121 | 0.221 |
| PH | 7.10 | 0.049 | 7.05 | 7.21 |
| TEMP DEG C | 17.2 | 0.558 | 16.7 | 17.8 |

PLANT MS06
7 SAMPLES

Table 113. OYSTER FRESH/FROZEN PROCESS
(HAND SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.153 | 0.011 | 0.138 | 0.164 |
| PROCESS TIME HR/DAY | 7.50 | -- | 5.50 | 8.00 |
| FLOW L/SEC | 2.23 | 0.090 | 2.12 | 2.33 |
| (GAL/MIN) | 35.4 | 1.43 | 33.7 | 37.0 |
| FLOW RATIO L/KKG | 56400 | 697 | 55800 | 57400 |
| (GAL/TON) | 13500 | 167 | 13400 | 13800 |
| SETT. SOLIDS ML/L | 2.05 | 0.281 | 1.75 | 2.36 |
| RATIO L/KKG | 116 | 15.9 | 98.5 | 133 |
| SCR. SOLIDS MG/L | 124 | 26.1 | 104 | 168 |
| RATIO KG/KKG | 7.01 | 1.47 | 5.89 | 9.48 |
| SUSP. SOLIDS MG/L | 618 | 27.6 | 583 | 650 |
| RATIO KG/KKG | 34.8 | 1.56 | 32.9 | 36.7 |
| 5 DAY BOD MG/L | 406 | 52.5 | 330 | 476 |
| RATIO KG/KKG | 22.9 | 2.96 | 18.6 | 26.9 |
| COD MG/L | 729 | 87.8 | 608 | 848 |
| RATIO KG/KKG | 41.2 | 4.95 | 34.3 | 47.9 |
| GREASE & OIL MG/L | 30.1 | 6.12 | 25.3 | 38.5 |
| RATIO KG/KKG | 1.70 | 0.345 | 1.43 | 2.17 |
| ORGANIC-N MG/L | 63.2 | 8.59 | 51.5 | 74.6 |
| RATIO KG/KKG | 3.57 | 0.484 | 2.90 | 4.21 |
| AMMONIA-N MG/L | 1.81 | 0.414 | 1.43 | 2.46 |
| RATIO KG/KKG | 0.102 | 0.023 | 0.081 | 0.139 |
| PH | 6.66 | 0.052 | 6.60 | 6.73 |
| TEMP DEG C | 10.00 | -- | -- | -- |

PLANT H508
5 SAMPLES

## Table 114. OYSTER FRESH/FROZEN PROCESS
## (HAND SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.380 | 0.028 | 0.360 | 0.400 |
| PROCESS TIME HR/DAY | 4.75 | -- | 4.50 | 5.00 |
| FLOW L/SEC | 2.72 | 0.120 | 2.64 | 2.81 |
| (GAL/MIN) | 43.2 | 1.91 | 41.9 | 44.6 |
| FLOW RATIO L/KKG | 28700 | 2700 | 26800 | 30600 |
| (GAL/TON) | 6880 | 648 | 6420 | 7340 |
| SETT. SOLIDS ML/L | 2.18 | 0.620 | 1.74 | 2.62 |
| RATIO L/KKG | 62.6 | 17.8 | 50.0 | 75.1 |
| SCR. SOLIDS MG/L | 312 | 97.4 | 243 | 381 |
| RATIO KG/KKG | 8.96 | 2.80 | 6.99 | 10.9 |
| SUSP. SOLIDS MG/L | 490 | 108 | 413 | 566 |
| RATIO KG/KKG | 14.1 | 3.11 | 11.9 | 16.3 |
| 5 DAY BOD MG/L | 1030 | 165 | 916 | 1150 |
| RATIO KG/KKG | 29.6 | 4.75 | 26.3 | 33.0 |
| COD MG/L | 1610 | 228 | 1450 | 1770 |
| RATIO KG/KKG | 46.2 | 6.54 | 41.5 | 50.8 |
| GREASE & OIL MG/L | 37.3 | 9.12 | 30.8 | 43.7 |
| RATIO KG/KKG | 1.07 | 0.262 | 0.885 | 1.26 |
| ORGANIC-N MG/L | 255 | 26.5 | 236 | 274 |
| RATIO KG/KKG | 7.32 | 0.760 | 6.78 | 7.85 |
| AMMONIA-N MG/L | 4.72 | 0.047 | 4.69 | 4.75 |
| RATIO KG/KKG | 0.135 | 0.001 | 0.135 | 0.136 |
| PH | 6.89 | 0.228 | 6.72 | 7.18 |
| TEMP DEG C | 1.97 | -- | -- | -- |

PLANT HSC9
2 SAMPLES

## Table 115. OYSTER FRESH/FROZEN PROCESS (HAND-SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.031 | 0.009 | 0.025 | 0.037 |
| PROCESS TIME HR/DAY | 8.00 | — | — | — |
| FLOW L/SEC | 0.309 | 0.041 | 0.280 | 0.339 |
| (GAL/MIN) | 4.91 | 0.656 | 4.45 | 5.38 |
| FLOW RATIO L/KKG | 37100 | 1700 | 35900 | 38300 |
| (GAL/TON) | 8890 | 407 | 8600 | 9180 |
| SETT. SOLIDS ML/L | 1.67 | 0.314 | 1.45 | 1.90 |
| RATIO L/KKG | 62.1 | 11.7 | 53.8 | 70.3 |
| SCR. SOLIDS MG/L | 245 | 83.5 | 186 | 304 |
| RATIO KG/KKG | 9.07 | 3.10 | 6.88 | 11.3 |
| SUSP. SOLIDS MG/L | 416 | 105 | 342 | 491 |
| RATIO KG/KKG | 15.4 | 3.89 | 12.7 | 18.2 |
| 5 DAY BOD MG/L | 619 | 78.1 | 564 | 674 |
| RATIO KG/KKG | 23.0 | 2.90 | 20.9 | 25.0 |
| COD MG/L | 1450 | 182 | 1320 | 1580 |
| RATIO KG/KKG | 53.6 | 6.75 | 48.9 | 58.4 |
| GREASE & OIL MG/L | 42.9 | 4.53 | 39.7 | 46.1 |
| RATIO KG/KKG | 1.59 | 0.168 | 1.47 | 1.71 |
| ORGANIC-N MG/L | 129 | 16.3 | 118 | 141 |
| RATIO KG/KKG | 4.78 | 0.605 | 4.36 | 5.21 |
| AMMONIA-N MG/L | 2.15 | 0.202 | 2.01 | 2.29 |
| RATIO KG/KKG | 0.080 | 0.007 | 0.074 | 0.085 |
| PH | 6.73 | 0.026 | 6.71 | 6.75 |
| TEMP DEG C | 10.00 | — | — | — |

PLANT HS10
2 SAMPLES

## Table 116. OYSTER FRESH/FROZEN PROCESS
## (HAND-SHUCKED)

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.150 | -- | -- | -- |
| PROCESS TIME HR/DAY | 8.00 | -- | -- | -- |
| FLOW L/SEC | 1.52 | 0.149 | 1.41 | 1.72 |
| (GAL/MIN) | 24.1 | 2.36 | 22.3 | 27.3 |
| FLOW RATIO L/KKG | 40200 | 3940 | 37300 | 45600 |
| (GAL/TON) | 9630 | 945 | 8930 | 10900 |
| SETT. SOLIDS ML/L | 4.42 | 0.602 | 3.91 | 5.03 |
| RATIO L/KKG | 178 | 24.2 | 157 | 202 |
| SCR. SOLIDS MG/L | 599 | 477 | 274 | 1170 |
| RATIO KG/KKG | 24.1 | 19.2 | 11.0 | 47.2 |
| SUSP. SOLIDS MG/L | 961 | 130 | 838 | 1140 |
| RATIO KG/KKG | 38.6 | 5.24 | 33.7 | 45.6 |
| 5 DAY BOD MG/L | 611 | 78.9 | 511 | 711 |
| RATIO KG/KKG | 24.6 | 3.17 | 20.5 | 28.6 |
| COD MG/L | 1370 | 169 | 1250 | 1640 |
| RATIO KG/KKG | 55.2 | 6.78 | 50.3 | 65.8 |
| GREASE & OIL MG/L | 39.5 | 5.62 | 31.1 | 47.6 |
| RATIO KG/KKG | 1.59 | 0.226 | 1.25 | 1.91 |
| ORGANIC-N MG/L | 231 | 16.2 | 221 | 257 |
| RATIO KG/KKG | 9.30 | 0.652 | 8.88 | 10.3 |
| AMMONIA-N MG/L | 2.65 | 0.331 | 2.31 | 3.24 |
| RATIO KG/KKG | 0.107 | 0.013 | 0.093 | 0.130 |
| PH | 7.00 | 0.129 | 6.86 | 7.24 |
| TEMP DEG C | 10.00 | -- | -- | -- |

PLANT HS11
4 SAMPLES

## Table 117. SCALLOPS FREEZING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.48 | 0.226 | 1.21 | 1.71 |
| PROCESS TIME HR/DAY | 5.77 | — | 3.30 | 8.00 |
| FLOW L/SEC | 5.00 | 0.784 | 4.22 | 6.34 |
| (GAL/MIN) | 79.5 | 12.5 | 67.0 | 101 |
| FLOW RATIO L/KKG | 13600 | 2550 | 10100 | 17400 |
| (GAL/TON) | 3270 | 611 | 2410 | 4170 |
| SETT. SOLIDS ML/L | 0.133 | 0.054 | 0.074 | 0.215 |
| RATIO L/KKG | 1.81 | 0.741 | 1.01 | 2.93 |
| SCR. SOLIDS MG/L | 448 | 122 | 306 | 584 |
| RATIO KG/KKG | 6.11 | 1.66 | 4.18 | 7.97 |
| SUSP. SOLIDS MG/L | 26.6 | 9.25 | 14.7 | 40.6 |
| RATIO KG/KKG | 0.363 | 0.126 | 0.201 | 0.555 |
| 5 DAY BOD MG/L | 199 | 67.7 | 98.8 | 285 |
| RATIO KG/KKG | 2.72 | 0.924 | 1.35 | 3.88 |
| COD MG/L | 321 | 78.1 | 200 | 396 |
| RATIO KG/KKG | 4.39 | 1.07 | 2.73 | 5.41 |
| GREASE & OIL MG/L | 15.2 | 14.8 | 3.61 | 31.9 |
| RATIO KG/KKG | 0.208 | 0.202 | 0.049 | 0.435 |
| ORGANIC-N MG/L | 56.5 | 34.4 | 19.7 | 102 |
| RATIO KG/KKG | 0.771 | 0.470 | 0.269 | 1.39 |
| AMMONIA-N MG/L | 2.71 | 0.724 | 1.93 | 3.92 |
| RATIO KG/KKG | 0.037 | 0.010 | 0.026 | 0.054 |
| PH | 6.86 | 0.184 | 6.56 | 7.19 |
| TEMP DEG C | 11.1 | 0.680 | 10.6 | 12.2 |

PLANT SP1
6 SAMPLES

## Table 118. SCALLOP FREEZING PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 1.05 | -- | -- | -- |
| PROCESS TIME HR/DAY | 11.5 | -- | -- | -- |
| FLOW L/SEC | 0.089 | -- | -- | -- |
| (GAL/MIN) | 1.42 | -- | -- | -- |
| FLOW RATIO L/KKG | 338 | -- | -- | -- |
| (GAL/TON) | 81.0 | -- | -- | -- |
| SETT. SOLIDS ML/L | 32.0 | -- | -- | -- |
| RATIO L/KKG | 10.8 | -- | -- | -- |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 3970 | -- | -- | -- |
| RATIO KG/KKG | 1.34 | -- | -- | -- |
| 5 DAY BOD MG/L | 10700 | -- | -- | -- |
| RATIO KG/KKG | 3.61 | -- | -- | -- |
| COD MG/L | 11300 | -- | -- | -- |
| RATIO KG/KKG | 3.82 | -- | -- | -- |
| GREASE & OIL MG/L | 26.0 | -- | -- | -- |
| RATIO KG/KKG | 0.009 | -- | -- | -- |
| ORGANIC-N MG/L | 1740 | -- | -- | -- |
| RATIO KG/KKG | 0.586 | -- | -- | -- |
| AMMONIA-N MG/L | 77.1 | -- | -- | -- |
| RATIO KG/KKG | 0.026 | -- | -- | -- |
| PH | 6.30 | -- | -- | -- |
| TEMP DEG C | 5.55 | -- | -- | -- |

PLANT SP2
1 SAMPLE

Table 119. Abalone fresh/frozen process material balance

Wastewater Material Balance Summary

| Unit Operation | % of Total Flow | % of Total BOD | % of Total Susp. Solids |
|---|---|---|---|
| a) process water | 49% | 50% | 39% |
| b) wash tank | 26% | 20% | 42% |
| c) washdown | 25% | 30% | 19% |
| Total effluent average AB1 | 47,100 l/kkg | 27 kg/kkg | 11 kg/kkg |

Product Material Balance Summary

| End Product | % of Raw Product |
|---|---|
| Food Products | |
| a) steaks | 38 - 42% |
| b) trimmings (patties, canned) | 34 - 36% |
| By-products | |
| a) shell | 10 - 12% |
| Wastes | |
| a) viscera | 10 - 12% |

Average Production Rate, .34 kkg/day (.38 tons/day)

The remaining source of wastewater is the washdown of the entire processing area. Tables 120 through 122 show the wastewater characteristics of the three plants sampled. These tables show that relatively large amounts of water and wastes are generated per ton of product compared to other seafood processing operations.

## Product Material Balance

The production rates of abalone plants are quite low, with an average of 0.183 kkg/day (0.202 tons/day). The input also varies considerably due to fluctuations in raw product availability.

Table 119 shows the breakdown of raw product into food product, by-product, and waste. The recovery of food product varies with species and whether the abalone are packed whole or prepared as steaks. The average recovery of sliced steaks is approximately 38 to 42 percent. Good quality trimmings are retained along with low quality steaks for the production of abalone patties. The weight of trimmings is usually around the same as the net weight of the steaks recovered.

The abalone shells are retained for sale to curio shops and to producers of jewelry and gift items. These shells constitute the only by-product recovery at present. The viscera was collected as solid waste and turned over to the municipalities for disposal.

## Determination of Subcategory Summary Data

The computation of the subcategory summary data for the flow ratio, total suspended solids, $BOD_5$, and grease and oil parameters is based, in general, on the log-normal transform of individual plant summary data. The plants which were used to compute these subcategory-wide (spatial) averages are considered to be typical in their water and waste control practices. Plants which employed hybrid or partial processes were not included in the averages.

The log-normal transform incorporated weighing factors for the number of samples collected at each individual plant and for the temporal variabity of the individual plant data. Figure 71 presents the log-normal formulas utilized to calculate the subcategory parameter averages and standard deviations for the fish meal, hand-butchered salmon, mechanized salmon, conventional bottom fish, mechanized bottom fish, Pacific Coast hand-shucked oyster, and East and Gulf Coast hand-shucked oyster processing subcategories.

An unweighted log normal distribution was utilized to calculate the remaining subcategory averages even though the elimination of the weighing factors results in higher subcategory raw waste loads. However, the deletion of the weighing factors increases the data base because historical data which has already been reduced to temporal averages and plant data which does not include temporal variability can be utilized in the calculations.

Table 120 . ABALONE FRESH/FROZEN PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.072 | 0.019 | 0.048 | 0.087 |
| PROCESS TIME HR/DAY | 5.23 | -- | 4.20 | 7.50 |
| FLOW L/SEC | 0.604 | 0.054 | 0.517 | 0.676 |
| (GAL/MIN) | 9.58 | 0.863 | 8.20 | 10.7 |
| FLOW RATIO L/KKG | 47100 | 14000 | 31200 | 69000 |
| (GAL/TON) | 11300 | 3370 | 7490 | 16500 |
| SETT. SOLIDS ML/L | 4.80 | 3.78 | 2.27 | 10.7 |
| RATIO L/KKG | 226 | 178 | 107 | 505 |
| SCR. SOLIDS MG/L | 95.4 | 13.2 | 85.4 | 105 |
| RATIO KG/KKG | 4.50 | 0.620 | 4.02 | 4.97 |
| SUSP. SOLIDS MG/L | 237 | 91.3 | 143 | 410 |
| RATIO KG/KKG | 11.2 | 4.30 | 6.74 | 19.4 |
| 5 DAY BOD MG/L | 579 | 228 | 302 | 885 |
| RATIO KG/KKG | 27.3 | 10.8 | 14.2 | 41.7 |
| COD MG/L | 917 | 356 | 468 | 1430 |
| RATIO KG/KKG | 43.2 | 16.8 | 22.1 | 67.3 |
| GREASE & OIL MG/L | 22.5 | 9.06 | 12.6 | 42.0 |
| RATIO KG/KKG | 1.06 | 0.427 | 0.595 | 1.98 |
| ORGANIC-N MG/L | 89.8 | 33.5 | 46.2 | 135 |
| RATIO KG/KKG | 4.23 | 1.58 | 2.18 | 6.34 |
| AMMONIA-N MG/L | 4.04 | 1.58 | 1.85 | 6.49 |
| RATIO KG/KKG | 0.190 | 0.075 | 0.087 | 0.306 |
| PH | 7.17 | 0.185 | 6.89 | 7.62 |
| TEMP DEG C | 20.3 | 1.72 | 19.1 | 21.4 |

PLANT AB1
4 SAMPLES

## Table 121. ABALONE FRESH/FROZEN PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.045 | -- | -- | -- |
| PROCESS TIME HR/DAY | 2.20 | -- | -- | -- |
| FLOW L/SEC | 0.583 | -- | -- | -- |
| (GAL/MIN) | 9.25 | -- | -- | -- |
| FLOW RATIO L/KKG | 50900 | -- | -- | -- |
| (GAL/TON) | 12200 | -- | -- | -- |
| SETT. SOLIDS ML/L | 4.09 | -- | -- | -- |
| RATIO L/KKG | 208 | -- | -- | -- |
| SCR. SOLIDS MG/L | -- | -- | -- | -- |
| RATIO KG/KKG | -- | -- | -- | -- |
| SUSP. SOLIDS MG/L | 317 | -- | -- | -- |
| RATIO KG/KKG | 16.1 | -- | -- | -- |
| 5 DAY BOD MG/L | 431 | -- | -- | -- |
| RATIO KG/KKG | 22.0 | -- | -- | -- |
| COD MG/L | 1010 | -- | -- | -- |
| RATIO KG/KKG | 51.2 | -- | -- | -- |
| GREASE & OIL MG/L | 29.8 | -- | -- | -- |
| RATIO KG/KKG | 1.52 | -- | -- | -- |
| ORGANIC-N MG/L | 46.0 | -- | -- | -- |
| RATIO KG/KKG | 2.35 | -- | -- | -- |
| AMMONIA-N MG/L | 2.19 | -- | -- | -- |
| RATIO KG/KKG | 0.111 | -- | -- | -- |
| PH | 6.91 | -- | -- | -- |
| TEMP DEG C | -- | -- | -- | -- |

PLANT AB2
1 SAMPLE

## Table 122. ABALONE FRESH/FROZEN PROCESS

| PARAMETER | MEAN | STD DEV | MINIMUM | MAXIMUM |
|---|---|---|---|---|
| PRODUCTION TON/HR | 0.069 | 0.005 | 0.067 | 0.075 |
| PROCESS TIME HR/DAY | 2.33 | — | 1.50 | 4.00 |
| FLOW L/SEC | 0.437 | 0.134 | 0.328 | 0.611 |
| (GAL/MIN) | 6.94 | 2.13 | 5.21 | 9.70 |
| FLOW RATIO L/KKG | 25200 | 8590 | 18400 | 36400 |
| (GAL/TON) | 6050 | 2060 | 4410 | 8730 |
| SETT. SOLIDS ML/L | 2.47 | 1.16 | 1.21 | 3.50 |
| RATIO L/KKG | 62.2 | 29.2 | 30.6 | 88.3 |
| SCR. SOLIDS MG/L | 162 | 167 | 23.8 | 297 |
| RATIO KG/KKG | 4.08 | 4.21 | 0.599 | 7.48 |
| SUSP. SOLIDS MG/L | 298 | 78.0 | 198 | 388 |
| RATIO KG/KKG | 7.52 | 1.97 | 5.01 | 9.79 |
| 5 DAY BOD MG/L | 473 | 165 | 263 | 633 |
| RATIO KG/KKG | 11.9 | 4.15 | 6.64 | 16.0 |
| COD MG/L | 816 | 148 | 631 | 992 |
| RATIO KG/KKG | 20.6 | 3.72 | 15.9 | 25.0 |
| GREASE & OIL MG/L | 33.9 | 13.9 | 19.6 | 51.5 |
| RATIO KG/KKG | 0.854 | 0.352 | 0.494 | 1.30 |
| ORGANIC-N MG/L | 72.3 | 11.9 | 58.1 | 87.1 |
| RATIO KG/KKG | 1.82 | 0.299 | 1.47 | 2.20 |
| AMMONIA-N MG/L | 3.16 | 1.05 | 2.13 | 4.55 |
| RATIO KG/KKG | 0.080 | 0.026 | 0.054 | 0.115 |
| PH | 7.19 | 0.176 | 7.00 | 7.35 |
| TEMP DEG C | 20.6 | — | — | — |

PLANT AB3
3 SAMPLES

$$\ln \mu_s = \frac{\sum_{i=1}^{N} \left( \frac{n_i}{\ln\left(\frac{\sigma_i^2}{\mu_i^2} + 1\right)} \right) \left( \ln \mu_i - \frac{1}{2} \ln\left\{ \frac{\sigma_i^2}{\mu_i^2} + 1 \right\} \right)}{\sum_{i=1}^{N} \frac{n_i}{\ln\left\{\frac{\sigma_i^2}{\mu_i^2} + 1\right\}}}$$

$$\ln \sigma_s = \left[ \frac{\sum_{i=1}^{N} (n_i - 1) \left( \ln \frac{\sigma_i^2}{\mu_i^2} + 1 \right)}{\sum_{i=1}^{N} (n_i - 1)} \right]^{1/2}$$

Where $\ln \mu_s$ and $\ln \sigma_s$ are the parameter log-normal mean and standard deviation respectively; N is the total number of plants sampled; $\eta$ is the number of parameter samples of plant $i$; and $\mu_i$ and $\sigma_i$ are the parameter mean and standard deviation of plant $i$.

FIGURE 71 Log - normal formulas for the subcategory mean and standard deviation.

# SECTION VI

## SELECTION OF POLLUTANT PARAMETERS

### WASTEWATER PARAMETERS OF POLLUTIONAL SIGNIFICANCE

The waste water parameters of major pollutional significance to the canned and preserved seafood processing industry are: 5-day (20°C) biochemical oxygen demand (BOD$\underline{5}$), suspended solids, and oil and grease. For the purposes of establishing effluent limitations pH is included in the monitored parameters and must fall within an acceptable range. Of peripheral or occasional importance are temperature, phosphorus, coliforms, ultimate (20 day) biochemical oxygen demand, chloride, chemical oxygen demand (COD), settleable solids, and nitrogen.

On the basis of all evidence reviewed, no purely hazardous or toxic (in the accepted sense of the word) pollutants (e.g., heavy metals, pesticides, etc.) occur in wastes discharged from canned or preserved seafood processing facilities.

In high concentrations, both chloride and ammonia can be considered inhibitory (or occasionally toxic) to micro- and macro-organisms. At the levels usually encountered in fish and shellfish processing waters, these problems are not encountered, with one class of exceptions: high strength (occasionally saturated) NaCl solutions are periodically discharged from some segments of the industry. These can interfere with many biological treatment systems unless their influence is moderated by some form of dilution or flow equalization.

### Rationale For Selection Of Identified Parameters

The selection of the major waste water parameters is based primarily on prior publications in food processing waste characterization research (most notably, seafood processing waste characterization studies) (28). The EPA seafood state-of-the-art report "Current Practice in Seafood Processing Waste Treatment," (24) provided a comprehensive summary of the industry. All of these publications involved the evaluation of various pollutant parameters and their applicability to food processing wastes.

The studies conducted at Oregon State University involving seafood processing wastes characterization included the following parameters:

1. temperature
2. pH
3. settleable solids
4. suspended solids
5. chemical oxygen demand
6. 5-day biochemical oxygen demand

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7. ultimate biochemical oxygen demand
8. oil and grease
9. nitrate
10. total Keldahl nitrogen (organic nitrogen and ammonia)
11. phosphorus
12. chloride
13. coliform

Of all these parameters, it was demonstrated (29) that those listed above as being of major pollutional significance were the most significant. The results of the current study (Section V) support this conclusion. Below are discussions of the rationale used in arriving at those conclusions.

### 1. Biochemical Oxygen Demand (BOD5)

Two general types of pollutants can exert a demand on the dissolved oxygen regime of a body of receiving water. These are: 1) chemical species which exert an immediate dissolved oxygen demand (IDOD) on the water body due to chemical reactions; and 2) organic substances which indirectly cause a demand to be exerted on the system because indigenous microorganisms utilizing the organic wastes as substrate flourish and proliferate; their natural respiratory activity utilizing the surrounding dissolved oxygen. Seafood wastes do not contain constituents that exert an immediate demand on a receiving water. They do, however, contain high levels of organics whose strength is most commonly measured by the BOD5 test.

The biochemical oxygen demand is usually defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. The term "decomposable" may be interpreted as meaning that the organic matter can serve as food for the bacteria and energy is derived from this oxidation.

The BOD does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Seafood processing and other organic effluents exert a BOD during their processes of decomposition which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill all inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations.

The $BOD_5$ test is widely used to determine the pollutional strength of domestic and industrial wastes in terms of the oxygen that they will require if discharged into natural watercourses in which aerobic conditions exist. The test is one of the most important in stream polluton control activities. By its use, it is possible to determine the degree of pollution in streams at any time. This test is of prime importance in regulatory work and in studies designed to evaluate the purification capacities of receiving bodies of water.

The $BOD_5$ test is essentially a bioassay procedure involving the measurement of oxygen consumed by living organisms while utilizing the organic matter present in a waste under conditions as similar as possible to those that occur in nature. The problem arises when the test must be standardized to permit its use (for comparative purposes) on different samples, at different times, and in different locations. Once "standard conditions" have been defined, as they have (Standard Methods, 1971) for the $BOD_5$ test, then the original assumption that the analysis simulates natural conditions in the receiving waters no longer applies, except only occasionally.

In order to make the test quantitative the samples must be protected from the air to prevent reaeration as the dissolved oxygen level diminishes. In addition, because of the limited solubility of oxygen in water (about 9 mg/l at 20°C), strong wastes must be diluted to levels of demand consistent with this value to ensure that dissolved oxygen will be present throughout the period of the test.

Since this is a bioassay procedure, it is extremely important that environmental conditions be suitable for the living organisms to function in an unhindered manner at all times. This requirement means that toxic substances must be absent and that accessory nutrients needed for microbial growth (such as nitrogen, phosphorus and certain trace elements) must be present. Biological degradation of organic matter under natural conditions is brought about by a diverse group of organisms that carry the oxidation essentially to completion (i.e., almost entirely to carbon dioxide and water). Therefore, it is important that a mixed group of organisms commonly called "seed" be present in the test.

The BOD5 test may be considered as a wet oxidation procedure in which the living organisms serve as the medium for oxidation of the organic matter to carbon dioxide and water. A quantitative relationship exists between the amount of oxygen required to convert a definite amount of any given organic compound to carbon dioxide and water which can be represented by a generalized equation. On the basis of this relationship it is possible to interpret BOD5 data in terms of organic matter as well as in terms of the amount of oxygen used during its oxidation. This concept is fundamental to an understanding of the rate at which BOD5 is exerted.

The oxidative reactions involved in the BOD5 test are results of biological activity and the rate at which the reactions proceed is governed to a major extent by population numbers and temperature. Temperature effects are held constant by performing the test at 20°C, which is more or less a median value for natural bodies of water. The predominant organisms responsible for the stabilization of most organic matter in natural waters are native to the soil.

The rate of their metabolic processes at 20°C and under the conditions of the test (total darkness, quiescence, etc.) is such that time must be reckoned in days. Theoretically, an infinite time is required for complete biological oxidation of organic matter, but for all practical purposes the reaction may be considered to be complete in 20 days. A BOD test conducted over the 20 day period is normally considered a good estimate of the "ultimate BOD." However, a 20 day period is too long to wait for results in most instances. It has been found by experience with domestic sewage that a reasonably large percentage of the total BOD is exerted in five days. Consequently, the test has been developed on the basis of a 5-day incubation period. It should be remembered, therefore, that 5-day BOD values represent only a portion of the total BOD. The exact percentage depends on the character of the "seed" and the nature of the organic matter and can be determined only by experiment. In the case of domestic and some industrial waste waters it has been found that the BOD5 value is about 70 to 80 percent of the total BOD. An analysis of the ratio of 20-day BOD to 5-day BOD was made using the data base of this study. The average and standard deviation of the ratios were computed as well as the correlation coefficient. This analysis indicates that the 5-day BOD averaged 58 percent of the 20-day BOD for the finfish commodities and 60 percent for the shellfish commodities. The details are discussed later in this section.

## 2. Suspended Solids

This parameter measures the suspended material that can be removed from the waste waters by laboratory filtration but does not include coarse or floating matter that can be screened or settled out readily. Suspended solids are a vital and easily determined measure of pollution and also a measure of the material that may settle in tranquil or slow moving streams. Suspended solids in the raw wastes from seafood processing plants correlate well with BOD$_5$ and COD. Often, a high level of suspended solids serves as an indicator of a high level of BOD$_5$. Suspended solids are the primary parameter for measuring the effectiveness of solids removal systems such as screens, clarifiers and flotation units. After primary treatment, suspended solids no longer correlate with organics content because a high percentage of the BOD$_5$ in fish processing waste waters is soluble or colloidal.

Suspended solids include both organic and inorganic materials. The inorganic components may include sand, silt, and clay. The organic fraction includes such materials as grease, oil, animal and vegetable fats, and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the receiving water with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises.

Solids may be suspended in water for a time, and then settle to the bed of the receiving water. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the receiving water bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the receiving water and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic, and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludgeworms and associated organisms.

Turbidity is principally a measure of the light absorbing properties of suspended solids. It is frequently used as a substitute method of quickly estimating the total suspended solids when the concentration is relatively low.

### 3. Oil and Grease

Although with the foregoing analyses the standard procedures as described in the 13th edition of Standard Methods (1971), are applicable to seafood processing wastes, this appears not necessarily to be the case for "floatables." The standard method for determining the oil and grease level in a sample involves multiple solvent extraction of the filterable portion of the sample with n-hexane or trichlorotrifluorethane (Freon) in a soxhlet extraction apparatus. As cautioned in Standard Methods, (1971) this determination is not an absolute measurement producing solid, reproducible, quantitative results. The method measures, with various accuracies, fatty acids, soaps, fats, waxes, oils and any other material which is extracted by the solvent from an acidified sample and which is not volatilized during evaporation of the solvent. Of course the initial assumption is that the oils and greases are separated from the aqueous phase of the sample in the initial filtration step. Acidification of the sample is said to greatly enhance recovery of the oils and greases therein (Standard Methods,1971).

Oils and greases are particularly important in the seafood processing industries because of their high concentrations and the nuisance conditions they cause when allowed to be discharged untreated to a watercourse. Also, oil and grease are notably resistant to anaerobic digestion and when present in an anaerobic system cause excessive scum accumulation, clogging of the pores of filters, etc., and reduce the quality of the final sludge. It is, therefore, important that oils and greases be measured routinely in seafood processing waste waters and that their concentrations discharged to the environment be minimized.

Previous work with seafood had indicated that the Standard Methods (1971) oil and grease procedure was inadequate for some species. In a preliminary study the standard method recovered only 16 percent of a fish oil sample while recovering 99 percent of a vegetable oil sample. To obviate the problem a modification to Standard Methods was used as discussed under Analytical Methods later in this section. The loss using the modification was reduced to about 5 to 15 percent.

The follwing general comments may pertain to animal, vegatable, or petroleum based greases and oils.

Grease and oil exhibit an oxygen demand. Oil emulsions may adhere to the gills of fish or coat and destroy algae or other plankton. Deposition of oil in the bottom sediments can serve to inhibit normal benthic growths, thus interrupting the aquatic food chain. Soluble and emulsified material ingested by fish may taint the flavor of the fish flesh. Water soluble components may exert toxic action on fish. Floating oil may reduce the re-aeration of the water surface and in conjunction with emulsified oil may interfere with photosynthesis. Water insoluble components damage the plumage and coats of water animals and fowls. Oil and grease in a water can result in the formation of objectionable surface slicks preventing the full aesthetic enjoyment of the water.

Oil spills can damage the surface of boats and can destroy the aesthetic characteristics of beaches and shorelines.

### 4. pH, Acidity and Alkalinity

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH, water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

For these reasons pH is included as a monitored effluent limitation parameter even though the majority of seafood processing waste waters is near neutrality prior to treatment.

## Minor Parameters

Of the minor parameters mentioned in the introduction to this section, eight were listed: ultimate BOD, COD, phosphorus, nitrogen, temperature, settleable solids, coliforms, and chloride. Of these eight, two are considered peripheral and six are considered of occasional importance. Of peripheral importance are ultimate BOD and phosphorus. Phosphorus levels are sufficiently low to be of negligible importance, except under only the most stringent conditions, i.e., those involving eutrophication which dictate some type of tertiary treatment system. The ultimate BOD can be closely approximated with the COD test.

### 1. Chemical Oxygen Demand (COD)

The chemical oxygend demand (COD) represents an alternative to the biochemical oxygen demand, which in many respects is superior. The test is widely used and allows measurement of a waste in terms of the total quantity of oxygen required for oxidation to carbon dioxide and water under severe chemical and physical conditions. It is based on the fact that all organic compounds, with a few exceptions, can be oxidized by the action of strong oxidizing agents under acid conditions. Although amino nitrogen will be converted to ammonia nitrogen, organic nitrogen in higher oxidation states will be converted to nitrates; that is, it will be oxidized.

During the COD test, organic matter is converted to carbon dioxide and water regardless of the biological assimilability of the substances; for instance, glucose and lignin are both oxidized completely. As a result, COD values are greater than BOD values and may be much greater when significant amounts of biologically resistant organic matter is present. In the case of seafood processing wastes, this does not present a problem, as is demonstrated by the BOD/COD ratio analysis which was made during this study. This analysis showed that the average 5-day BOD to

COD ratio was 0.38 for the industrial fish, was 0.55 for the finfish commodities, and 0.66 for the shellfish commodities. Details of this analysis are presented later in this section.

One drawback of the COD test is its inability to demonstrate the rate at which the biologically active material would be stabilized under conditions that exist in nature. In the case of seafood processing wastes, this same drawback is applicable to the BOD test, because the strongly soluble nature of seafood processing wastes lends them to more rapid biological oxidation than domestic wastes. Therefore, a single measurement of the biochemical oxygen demand at a given point in time (5 days) is no indication of the difference between these two rates.

Another drawback of the chemical oxygen demand is analogous to a problem encountered with the BOD also; that is, high levels of chloride interfere with the analysis. Normally, 0.4 grams of mercuric sulfate are added to each sample being analyzed for chemical oxygen demand. This eliminates the chloride interference in the sample up to a chloride level of 40 mg/l. At concentrations above this level, further mercuric sulfate must be added. However, studies by the National Marine Fisheries Service Technological Laboratory in Kodiak, Alaska, on seafood processing wastes have indicated that above certain chloride concentrations the added mercuric sulfate itself causes interference (Tenny, 1972).

The major advantage of the COD test is the short time required for evaluation. The determination can be made in about 3 hours rather than the 5 days required for the measurement of BOD. Furthermore, the COD requires less sophisticated equipment, less highly-trained personnel, a smaller working area, and less investment in laboratory facilities. Another major advantage of the COD test is that seed acclimation need not be a problem. With the BOD test, the seed used to inoculate the culture should have been acclimated for a period of several days, using carefully prescribed procedures, to assure that the normal lag time (exhibited by all microorganisms when subjected to a new substrate) can be minimized. No acclimation, of course, is required in the COD test.

The possibility of substituting the COD parameter for the BOD5 parameter was investigated during this study. The BOD5 and corresponding COD data from industrial fish, finfish, and shellfish waste waters were analyzed to determine if COD is an adequate predictor of BOD5 for any or all of these groups of seafood. The analysis, which is presented later in this section, indicates tht the COD parameter is not a reliable predictor of BOD5.

Moreover, the relationship between COD and BOD5 before treatment is not necessarily the same after treatment. Therefore, the effluent limitations will include the BOD5 parameter, since insufficient information is available on the COD effluent levels after treatment.

## 2. Settleable Solids

The settleable solids test involves the quiescent settling of a liter of waste water in an "Imhoff cone" for one hour, with appropriate handling (scraping of the sides, etc.). The method is simply a crude measurement of the amount of material one might expect to settle out of the waste water under quiescent conditions. It is especially applicable to the analysis of waste waters being treated by such methods as screens, clarifiers and flotation units, for it not only defines the efficacy of the systems, in terms of settleable material, but provides a reasonable estimate of the amount of deposition that might take place under quiescent conditions in the receiving water after discharge of the effluent.

## 3. Ammonia and Nitrogen

Seafoods processing waste waters are highly proteinaceous in nature; total nitrogen levels of several thousand milligrams per liter are not uncommon. Most of this nitrogen is in the organic and ammonia form. These high nitrogen levels contribute to two major problems when the waste waters are discharged to receiving waters. First the nitrification of organic nitrogen and ammonia by indigineous microorganisms creates a sizable demand on the local oxygen resource. Secondly, in waters where nitrogen is the limiting element this enrichment could enhance eutrophication markedly. The accepted methods for measurement of organic and ammonia nitrogen, using the macro-kjeldahl apparatus as described in Standard Methods (1971), are adequate for the analysis of seafood processing wastewaters. It should be remembered that organic strengths of seafood processing waste waters are normally considerably higher than that of normal domestic sewage; therefore, the volume of acid used in the digestion process frequently must be increased. Standard Methods (1971) alerts the analyst to this possibility by mentioning that in the presence of large quantities of nitrogen-free organic matter, it is necessary to allow an additional 50 ml of sulfuric acid - mecuric sulfate - potassium sulfate digestion solution for each gram of solid material in the sample. Bearing this in mind, the analyst can, with assurance, monitor organic nitrogen and ammonia levels in fish and shellfish processing waste waters accurately and reproducibly.

Nitrogen parameters are not included in the effluent limitations because the extent to which nitrogen components in seafood wastes is removed by physical-chemical or biological treatment, remains to be evaluated. Furthermore, the need for advanced treatment technology specifically designed for nitorgen removal has not been demonstrated through this study. The following is a general parameter discussion of ammonia and nitrogen.

Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Ammonia exists in its non-ionized form only at higher pH levels and is the most toxic in this state. The lower the pH, the more ionized ammonia is formed and its toxicity decreases. Ammonia, in the presence of dissolved oxygen, is converted to nitrate ($NO_3$) by nitrifying bacteria. Nitrite ($NO_2$), which is an intermediate product between ammonia and nitrate, sometimes occurs in quantity when depressed oxygen conditions permit. Ammonia can exist in several other chemical combinations including ammonium chloride and other salts.

Nitrates are considered to be among the poisonous ingredients of mineralized waters, with potassium nitrate being more poisonous than sodium nitrate. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and the bladder; the symptoms are diarrhea and diuresis, and drinking one liter of water containing 500 mg/l of nitrate can cause such symptoms.

Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen ($NO_3$-N) should not be used for infants. Nitrates are also harmful in fermentation processes and can cause disagreeable tastes in beer. In most natural water the pH range is such that ammonium ions ($NH_4^+$) predominate. In alkaline waters, however, high concentrations of un-ionized ammonia in undissociated ammonium hydroxide increase the toxicity of ammonia solutions. In streams polluted with sewage, up to one half of the nitrogen in the sewage may be in the form of free ammonia, and sewage may carry up to 35 mg/l of total nitrogen. It has been shown that at a level of 1.0 mg/l un-ionized ammonia, the ability of hemoglobin to combine with oxygen is impaired and fish may suffocate. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 mg/l to 25 mg/l, depending on the pH and dissolved oxygen level present (48).

Ammonia can add to the problem of eutrophication by supplying nitrogen through its breakdown products. Some lakes in warmer climates, and others that are aging quickly are sometimes limited by the nitrogen available. Any increase will speed up the plant growth and decay process.

### 4. Temperature

Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development. Warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change, primary production is decreased, and bottom associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may cause aquatic plant nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms to green algae, and finally at high temperatures to blue-green algae, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 90°F, which is close to the tolerance limit for the population. This could seriously affect certain fish that depend on benthic organisms as a food source.

The cost of fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to the cooler water.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the esthetic value of a water course.

In general, marine water temperatures do not change as rapidly or range as widely as those of freshwaters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

Temperature is important in those seafood processing unit operations involving transfer of significant quantities of heat. These include evaporation, cooking, cooling of condensers, and the like. Since these operations represent only a minor aspect of the total process and their waste flows are generally of minor importance, temperature is not considered at this time to be a major parameter to be monitored.

### 5. Chloride

The presence of the chloride ion in the waters emanating from seafood processing plants is frequently of significance when considering biological treatment of the effluent. Those processes employing saline cooks, brine freezing, brine separation tanks (for segregating meat from shell in the crab industry, for instance) and seawater for processing, thawing, and/or cooling purposes, fall into this category. In consideration of biological treatment the chloride ion must be considered, especially with intermittent and fluctuating processes. Aerobic biological systems can develop a resistence to high chloride levels, but to do this they must be acclimated to the specific chloride level expected to be encountered; the subsequent chloride concentrations should remain within a fairly narrow range in the treatment plant influent. If chloride levels fluctuate widely, the resulting shock loadings on the biological system will reduce its efficiency at best, and will prove fatal to the majority of the microorganisms in the system at worst. For this reason, in situations where biological treatment is anticipated or is currently being practiced, measurement of chloride ion must be included in the list of parameters to be routinely monitored. The standard methods for the analysis of chloride ion are three fold: 1) the argentometric method, 2) the mercuric nitrate method and 3) the potentiometric method. The mercuric nitrate method has been found to be satisfactory with seafood processing waste waters. In some cases, the simple measurement of conductivity (with appropriate conversion tables) may suffice to give the analyst an indication of chloride levels in the waste waters.

## 6. Coliforms

Fecal coliforms are used as an indicator since they have originated from the intestinal tract of warm blooded animals. Their presence in water indicates the potential presence of pathogenic bacteria and viruses.

The presence of coliforms, more specifically fecal coliforms, in water is indicative of fecal pollution. In general, the presence of fecal coliform organisms indicates recent and possibly dangerous fecal contamination. When the fecal coliform count exceeds 2,000 per 100 ml there is a high correlation with increased numbers of both pathogenic viruses and bacteria.

Many microorganisms, pathogenic to humans and animals, may be carried in surface water, particularly that derived from effluent sources which find their way into surface water from municipal and industrial wastes. The diseases associated with bacteria include bacillary and amoebic dysentery, Salmonella gastroenteritis, typhoid and paratyphoid fevers, leptospirosis, chlorea, vibriosis and infectious hepatitis. Recent studies have emphasized the value of fecal coliform density in assessing the occurrence of Salmonella, a common bacterial pathogen in surface water. Field studies involving irrigation water, field crops and soils indicate that when the fecal coliform density in stream waters exceeded 1,000 per 100 ml, the occurrence of Salmonella was 53.5 percent. Fish, however, are cold blooded and no correlation has yet been developed between contamination by fish feces and effluent (or receiving water) coliform levels.

In a recent study undertaken by the Oregon State University under sponsorship of the Environmental Protection Agency, coliform levels (both total and fecal) in fish processing waste water were monitored routinely over a period of several months. Results were extremely inconsistent, ranging from zero to many thousands of coliforms per 100 ml sample. Attempts to correlate these variations with in-plant conditions, type and quality of product being processed, cleanup procedures, and so on, were unsuccessful. As a result, a graduate student was assigned the task of investigating these problems and identifying the sources of these large variabilities. The conclusions of this study can be found in the report; "Masters Project--Pathogen Indicator Densities and their Regrowth in Selected Tuna Processing Wastewaters" by H. W. Burwell, Department of Civil Engineering, Oregon State University, July 1973. Among his general conclusions were:

1. that coliform organisms are not a part of the natural biota present in fish intestines;
2. that the high suspended solid levels in waste water samples interferes significantly with subsequent analyses for coliform organisms and, in fact, preclude the use of the membrane filter technique for fish waste analysis;
3. that the analysis must be performed within foru hours after collection of the sample to obtain meaningful results (thus eliminating the possibility of the use of full-shift composite samples and also eliminating the possibility of sample preservation and shipment for remote analysis);
4. that considerable evidence exists that coliform regrowth frequently occurs in seafood processing waste water processing wastes) and that the degree of regrowth is a function of retention, time, waste water strength, and temperature.

The above rationale indicated that it would be inadvisable to consider further the possibility of including the coliform test in either the characterization phase of this study or in the list of parameters to be used in establishing effluent limitations.

### 7. Phosphorus

During the past 30 years, a formidable case has developed for the belief that increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man, frequently are caused by increasing supplies of phosphorus. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. It is generally recognized that phosphorus is not the sole cause of eutrophication, but there is evidence to substantiate that it is frequently the key element in all of the elements required by fresh water plants and is generally present in the least amount relative to need. Therefore, an increase in phosphorus allows use of other, already present, nutrients for plant growths. Phosphorus is usually described, for this reasons, as a "limiting factor."

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be eliminated because of the mass of vegetation that serves as an physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a desired substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic, and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 mg/l.

Phosphorus levels in seafood processing wastewaters are sufficiently low to be of negligible importance, except under only the most stringent conditions, i.e., those involving entrophication which dictate some type of tertiary treatment system.

## ANALYTICAL QUALITY CONTROL METHODS

A brief description of the analytical methods used to measure each parameter and the results of precision studies for the suspended solids, COD, grease and oil, and ammonia and organic nitrogen analyses are presented in the following portion of this section.

### Analytical Methods

The analytical methods for the samples collected for this project were based on Standard Methods for the Examination of Water and Wastewater, 13th Edition (1971) and Methods for the Chemical Analysis of Water and Wastes, E.P.A. (1971). There were a few minor modifications, since the organic content of the samples were extremely variable from one to another (e.g., BOD-5 of less than one to BOD-5 of more than 20,000 mg/l). A brief description of the analytical methods follows:

### Total suspended solids

Total suspended solids is reported in terms of screened solids and suspended solids. Screened samples were obtained from 20 mesh Tyler screen oversize particles and suspended solids by filtering the undersize through a 4.2 cm Whatman GF/C glass fiber filter. The screened and filtered solids were dried in an oven for one hour at about 104°C before weighing.

## Five-day BOD

Five-day BOD was determined according to Standard Methods. For samples with BOD-5 of higher than 20 mg/l, at least three different dilutions were made for each sample. The results among the different dilutions were generally less than ± 6%. The data reported were the average values of the different dilutions. For samples with BOD-5 of less than 20 mg/l, one or two dilutions with two duplicate bottles were incubated. Most of replicate BOD-5 in this low range were within ± 5%, but some had as much as ± 30% difference. Seed for the dilution water was a specially cultivated mixed culture in the laboratory using various fish wastes as the seed.

## Twenty-day BOD

Twenty-day BOD was determined using the same procedure as for five-day BOD except the bottles were incubated at 20°C for 20 days. Since most samples contained a high concentration of ammonia and organic nitrogen, nitrification during incubation frequently occurred. No attempt was made to supress nitrification during the incubation period, however the ratio of twenty-day BOD to five-day BOD appeared to be relatively consistent as discussed later in this section.

## Chloride

Chloride levels in the samples were determined for the purpose of making corrections for COD test. The argentometric method was used. Samples were adjusted to a pH of 7-8 and after addition of potassium chromate indicator, were titrated with 0.0282 N silver nitrate solution.

Since chloride correction was not necessary when the chloride level was below 1000 mg/l, a special screening technique was developed to sort out those samples with a chloride level of less than 1000 mg/l. One ml of sample was pipetted into a small beaker and diluted to 10 ml with distilled water. Three drops of phenolphthalein and 0.5 N sodium hydroxide were added dropwise until a pink color persisted. Then the sample was neutralized with 0.02 N sulfuric acid dropwise until the indicator showed a very faint pink color. This would make the sample pH about 8. To this, 1.0 ml of 0.0282 N silver nitrate was added. When the chloride level was less than 1000 mg/l, a definite reddish silver chromate precipitate was formed. The chloride level in these samples was reported as less than 1000 mg/l and no further precise determination was pursued.

When the chloride level was higher than 1000 mg/l, the red precipitate would not form when 1.0 ml of silver nitrate was added. In this case, the sample was titrated with 0.0282 N silver nitrate solution with a semimicroburet until the end point.

### Chemical oxygen demand

COD tests were based on Standard Methods (13th Edition) When the chloride content was less than 2000 mg/l, 0.4g of mercuric sulfate was added to the refluxing flask. If more chloride was present more mercuric sulfate was added to maintain a mercuric sulfate to chloride ratio of 10:1. Even this extra amount of mercuric sulfate did not prevent some chloride from being oxidized. Following the recommendation described in E.P.A.'s "Methods for Chemical Analysis of Water and Wastes," (1971) and by Burns and Marshall (Journal WPCF, Vol. 37, pp 1716-21, 1965), chloride correction curves were prepared using various concentrations of sodium chloride and a fixed concentration of potassium acid phthalate solution. No incomplete oxidation of phthalate solution was observed, in contrast to the results reported by Burns and Marshall.

For brine samples, as in the cases of intake water from an estuary (which had a low organic content), the precision was low for duplicate COD tests. The precision improved when the concentration of dichromate solution was reduced from 0.2N to 0.125N. Therefore, for the brine water samples which had a COD of less than 200 mg/l, 0.125N potassium dichromate solution was used. The chloride correction curves are shown in Figure 72.

### Grease and Oil

Grease and oil was determined by Soxhlet extraction using Freon 113 as the solvent, according to Standard Methods, 13th Edition.

All samples were acidified at the sampling site with sulfuric acid to a pH of less than 2. For samples with grease and oil content of higher than 10,000 mg/l, separation of grease and oil was poor and some modification of the Standard Methods was used. First, 100 ml of sample was transferred to a new cubitainer and diluted to 800 ml with distilled water. One ml of concentrated sulfuric acid was added to bring the pH to less than one and 80 grams of sodium chloride was added to salt out the grease and oil. After the sample was filtered, the cubitainer was cut open and the sides and bottom wiped out with freon soaked filter paper to remove any remaining solid material.

Two major sources of error were encountered in this test. Grease and oil which adhered to the original sample container were not removed since portions of the sample had to be used for other tests. This would give results less than true value. The loss was estimated to be about 5% to 15% for a grease and oil content in the 150 to 250 mg/l range.

The other major source of error (which resulted in a positive error), was that some very fine Celite particles seeped through

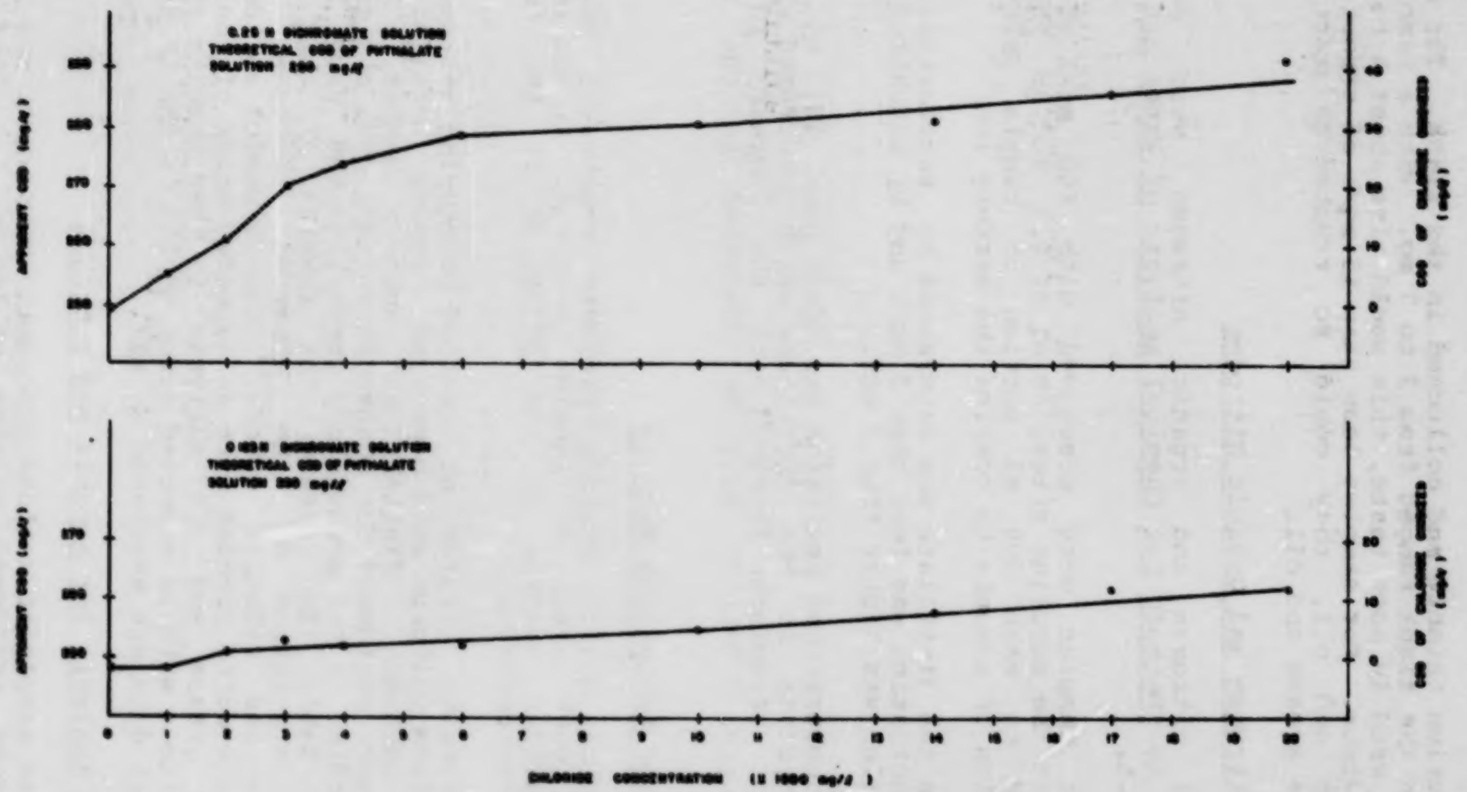

Figure 72. Chloride correction curves for COD determinations on seafood processing wastes.

the extraction thimble and collected in the flask. The amount of Celite in the flask ranged from 2 to 7 mg. With a sample volume of 500 ml used in most tests, this would give about 4 to 14 mg/l positive error. For samples less than 15 mg/l of reported values of grease and oil, they could be treated as practically no detectable grease and oil.

## Ammonia Nitrogen and Organic Nitrogen

Ammoniacal nitrogen and organic nitrogen were determined according to "Methods for Chemical Analysis of Water and Wastes," 1971, E.P.A.

Since the samples were preserved with 400 mg/l of mercuric chloride at the sampling sites, 60 ml of 0.1 sodium thiosulfate was added to each 200 ml portion of sample prior to the distillation of ammonia to complex the mercury ion.

Ammonia in the distillate was determined by Nesslerization when the concentration was less than 2 mg/l and by titration when the concentration was higher than 2 mg/l.

At low concentrations precision was often poor due to volatile amino compounds in the distillate which interfered with color development. Precision improved with the increase in ammonia concentration. Details will be discussed in the following section.

## Precision of Analytical Methods

For analytical quality control, periodic replicates tests were made for each batch of samples received. At the end of the project further studies on the precision of the analytical methods were conducted.

Three composite samples of seafood processing wastewater were prepared from sulfuric acid preserved samples containing clam, oyster, menhaden, finfish, and anchovy wastes. Replicate analyses were performed for suspended solids, COD, and grease and oil, according to the methodology prescribed and used for this project. Table 123 presents the results of this analysis including statistics on the observed averages, standard deviations and relative errors. The suspended solids and COD analyses are quite precise with an expected error of only about 2%. The grease and oil analysis is less precise at the low concentrations with an expected error of 14% in the 10 to 20 mg/l range. All data are expressed as mg/l.

## Percision Analysis for Ammonia and Nitrogen

A composite sample of seafood processing wastewater was prepared from mercury preserved samples collected for this project. Replicate analyses were performed on the sample for ammonia nitrogen and organic nitrogen using the methodology applied in this project. Table 124 presents the results of this analysis.

To determine the precision of the ammonia recovery over a range of concentrations the following analysis was conducted. The manual distillation method for ammonia nitrogen was used to recovery controlled increments of ammonium chloride from deionized water over a concentration range of 0.25 to 15 mg/l as ammonia. Nesslerization was used in the range 0.25 to 1.5 mg/l and titration with 0.02 sodium sulfate for the 1.5 to 15 mg/l levels. All samples were 200 ml. Table 125 shows that the expected error is relatively high, up to 15%, at the low concentrations (0.25 to 1.5 mg/l ammonia) but is less than 3% at the higher concentrations.

### Grease and oil recovery analysis

The precision of grease and oil recovery from a one liter cubitainer and a one liter beaker was determined as follows. A mixture of partially refined herring and menhaden oils was added in controlled increments to three composite samples by: a) shaking in a clean one liter cubitainer in which the residue was rinsed onto the filter with distilled water without attempting to wipe oil adhering to the plastic walls;

b) adding to a mixing sample in a one liter Pyrex beaker on a magnetic stirrer in which beaker walls and stirring bar were wiped with solvent-soaked cotton which was placed in an extraction thimble with filter.

Table 126 shows the results of this analysis. The percent recovery is equal to the grease and oil extracted after the addition of a spike of pure oil minus the average grease and oil contained in the composite before the oil was added, all divided by the amount of oil added. The loss in grease and oil recovery averages about 13 percent using the one liter cubitainer.

## PARAMETER ESTIMATION ANALYSIS

To minimize costs and effort it is desirable to describe the character of wastewater and the performance of treatment systems in terms of parameters which are easily measured. Since design parameters and operational performance data are often expressed in terms of parameters which are more difficult to measure, it is also desirable to be able to relate the easily measured to the more difficult to measure parameters. One example is the 5 day and 20 day BOD pair which are used to determine the rate that oxygen is consumed as a function of time. Another is the COD and 5 day BOD pair, where the COD is used to determine an estimate of the 5 day BOD which is a commonly reported parameter in the literature. An analysis was, therefore, conducted to determine the adequacy of estimating the 20 day BOD using the 5 day BOD and

Table 123. Summary of precision analyses for suspended solids, COD, and grease and oil.

| Trial Number | Composite A |  |  | Composite B |  |  | Composite C |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | SS | COD | G&O | SS | COD | G&O | SS | COD | G&O |
| 1 | 42 | 248 | 14 | 413 | 1250 | 66 | 8300 | 19800 | 1422 |
| 2 | 42 | 256 | 17 | 413 | 1260 | 60 | 7950 | 20300 | 1138 |
| 3 | 42 | 266 | 14 | 413 | 1260 | 68 | 7775 | 19300 | 1416 |
| 4 | 43 | 274 | 11 | 407 | 1240 | 58 | 7825 | 19400 | 1267 |
| 5 | 43 | 256 | 13 | 413 | 1260 | 54 | 7975 | 19600 | 1319 |
| 6 | 43 | 258 | 14 | 400 | 1270 | 51 | 8075 | 19600 | 1340 |
| 7 | 44 | 254 |  | 400 | 1260 | 71 | 8075 |  | 1290 |
| 8 |  | 266 |  |  | 1280 |  |  |  |  |
| 9 |  | 266 |  |  | 1290 |  |  |  |  |
| 10 |  | 258 |  |  | 1250 |  |  |  |  |
| Average | 42.7 | 260.2 | 13.8 | 408.4 | 1260.0 | 61.1 | 7996.4 | 19666 | 1313.1 |
| Standard Deviation | 0.75 | 7.63 | 1.94 | 6.16 | 14.76 | 7.45 | 175.85 | 355.9 | 97.06 |
| Relative Error | 1.8% | 2.9% | 14.0% | 1.5% | 1.2% | 12.2% | 2.2% | 1.8% | 7.4% |

Table 124. Summary of precision analyses for ammonia and organic nitrogen.

| Trial Number | Ammonia mg/l | Organic Nitrogen as Ammonia mg/l |
|---|---|---|
| 1 | 1.94 | 7.00 |
| 2 | 1.81 | 7.14 |
| 3 | 1.94 | 7.00 |
| 4 | 1.94 | 7.28 |
| 5 | 1.81 | 7.00 |
| 6 | 1.81 | 7.14 |
| Average Result | 1.87 | 7.09 |
| Standard Deviation | 0.071 | 0.114 |
| Relative Error | 3.8% | 1.6% |

Table 125. Summary of ammonia recovery precision analyses.

|  | Nessler Method |  |  |  | Titrate Method |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| mg/l $NH_3$ | .25 | .50 | 1.0 | 1.5 | 1.5 | 2.5 | 5 | 10 | 15 |
| microgram $NH_3$ 200 ml sample | 50 | 100 | 200 | 300 | 300 | 500 | 1000 | 2000 | 3000 |
| microgram $NH_3$ recovered | 56.5 | 85.9 | 170 | 378 | 233 | 429 | 924 | 1876 | 2828 |
|  | 58.3 | 82.6 | 173 | 379 | 267 | 420 | 924 | 1876 | 2856 |
|  | 58.1 | 90.9 | 176 | 348 | 267 | 448 | 924 | 1904 | 2828 |
|  | 42.8 |  |  | 290 | 226 | 420 | 924 |  |  |
|  | 67.7 |  |  | 281 | 196 |  | 924 |  |  |
|  | 65.6 |  |  | 354 | 234 |  | 924 |  |  |
| Average result | 58.2 | 86.1 | 173 | 338 | 237 | 429 | 924 | 1895 | 2837 |
| Average recovery % | 116 | 86.3 | 86 | 113 | 79 | 86 | 92 | 95 | 94 |
| Standard deviation | 8.78 | 4.29 | 3.00 | 42.9 | 26.9 | 13.2 | 0 | 16.2 | 16.2 |
| Relative error % | 15.1 | 5.0 | 1.7 | 12.7 | 11.3 | 3.1 | 0 | 0.8 | 0.6 |

### Table 126. Summary of grease and oil recovery precision analyses.

Cubitainer Recovery

| Sample | Oil Added to Composite mg/l | G&O Extracted mg/l | G&O Extracted Minus Avg G&O for Composite mg/l | % Recovery |
|---|---|---|---|---|
| Comp A | 162 | 145 | 132 | 81% |
| Comp A | 162 | 151 | 138 | 85% |
| Comp B | 162 | 211 | 150 | 93% |
| Comp B | 162 | 190 | 129 | 80% |
| Comp C | 800 | 2136 | 823 | 103% |
| Comp C | 800 | 1967 | 654 | 82% |

Beaker Recovery

| Sample | Oil Added to Composite mg/l | G&O Extracted mg/l | G&O Extracted Minus Avg G&O for Composite mg/l | % Recovery |
|---|---|---|---|---|
| Comp A | 80 | 109 | 96 | 120% |
| Comp A | 160 | 188 | 175 | 109% |
| Comp B | 160 | 224 | 163 | 98% |
| Comp B | 240 | 276 | 215 | 90% |
| Comp C | 1320 | 2851 | 1538 | 117% |
| Comp C | 2640 | 4329 | 3016 | 114% |

of estimating the 5 day BOD using the COD for different types of seafood wastewater.

The first problem in estimating one parameter using another is to establish the most tenable relationship between the two parameters and the most tenable error structure. The general form of the model is y = f(x) + e which says that the parameter y is equal to some function of x plus an error e. Three models commonly used are: the conventional regression model (y = A + Bx + e), the ratio of the means model (y = Rx + e'), and the mean of the ratio model (y = Rx + e").

The linear regression model is appropriate when it is not certain that the relation passes through the origin and when the variance of the error term is constant regardless of the value of x. In other words, the scatter diagram should show points which have about equal variability in the x dimension. Without performing an analysis of variance, it is obvious from the scatter diagrams developed (Figures 73 through 78) that the scatter is small for low values of x (5 day BOD or COD) and increases for higher values of x. This indicates that the linear regression model would not provide a good estimation of the desired parameter.

The ratio of the means estimator is unbiased when the parameters are equal at the origin and when the variance of the error increases linearly as a function of x. The mean of the ratios estimator is unbiased when the parameters are equal at the origin and variance of the error increases linearly as a function of x squared (30). There is good reason to believe that the parameters in both cases are equal to zero at the origin, however, it is difficult to determine which error structure is more correct. It appears, however, that the width of the scatter increases approximately proportional to the value of x, which means that the variance increases directly proportional to x squared. Based on these observations, the mean of the ratios was used to estimate the proportionality factor between the parameters. The unbiased estimator of the variance of the ratio was computed and the relative error determined for different types of seafood processing wastewater. The relative errors computed are considered to be conservative since the error variance was assumed to increase in proportion to x squared.

### 20 day BOD versus 5-day BOD

A limited number of samples (about 10 percent) obtained during this study were analyzed for 20 day BOD. The corresponding 20 day and 5 day BOD data were grouped into those from finfish and shellfish samples and plotted on scatter diagrams to observe possible relationships and error structures. Figures 73 and 74 show a good linear relation between 20 day and 5 day BOD for the finfish and a relatively good linear relation for the shellfish. The results of the ratio estimation calculations, including the number of samples used, the correlation coefficient, the mean of

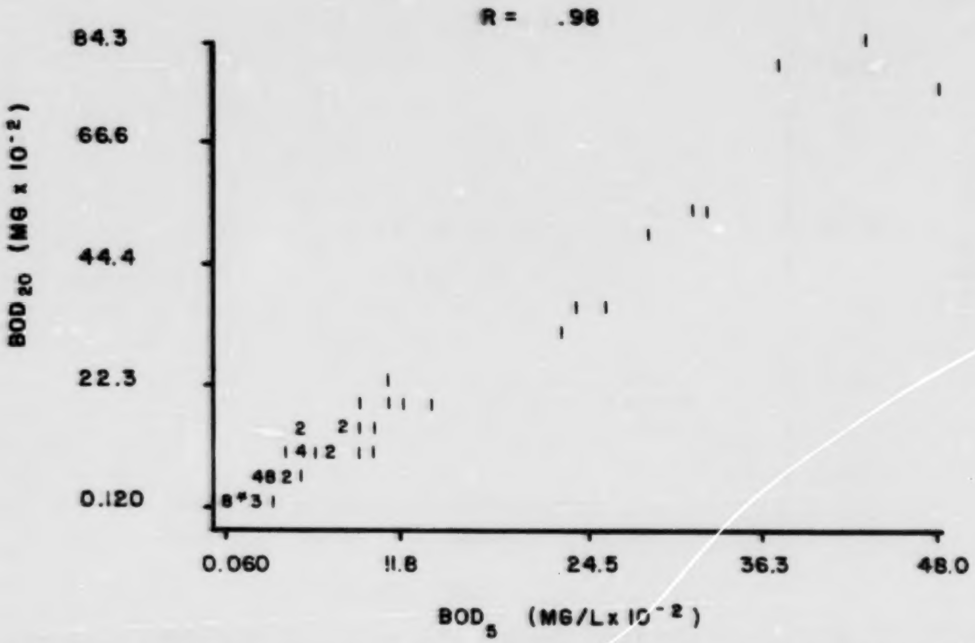

Figure 73. Finfish wastewater 20-day vs. 5-day BOD scatter diagram.

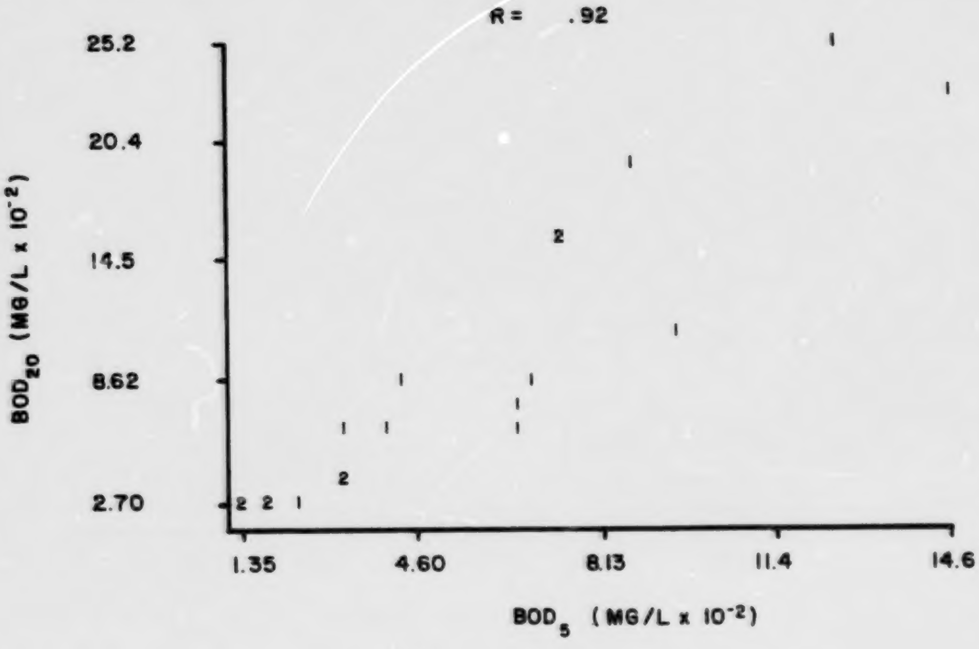

Figure 74 . Shellfish wastewater 20-day vs. 5-day BOD scatter diagram.

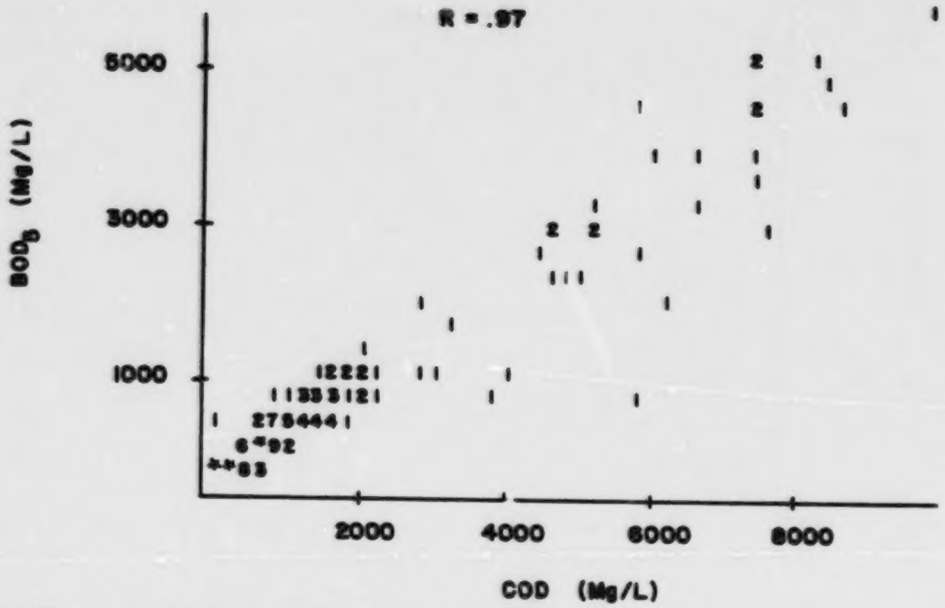

Figure 75. Seafood wastewater 5-day BOD vs. COD scatter diagram.

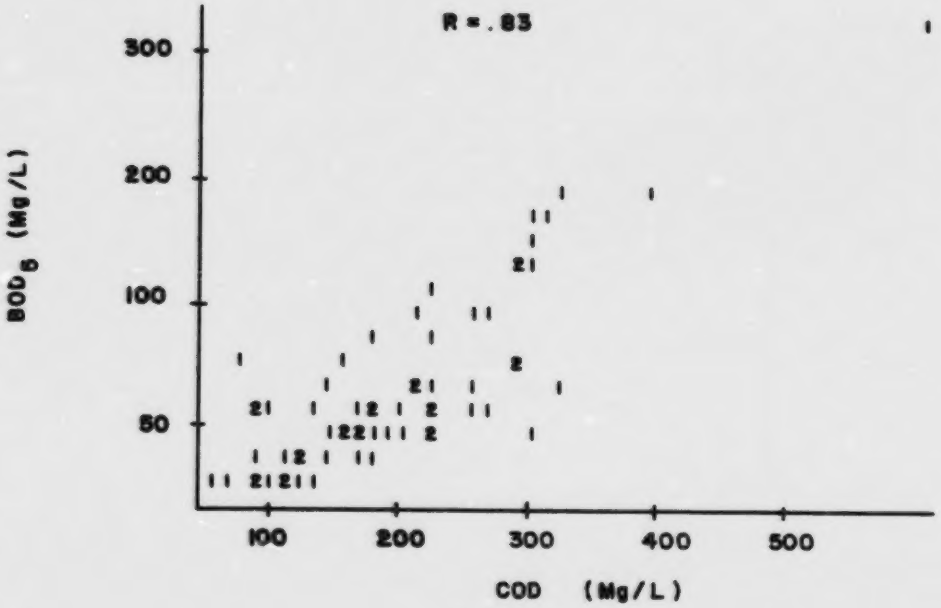

Figure 76. Industrial fish wastewater 5-day BOD vs. COD scatter diagram.

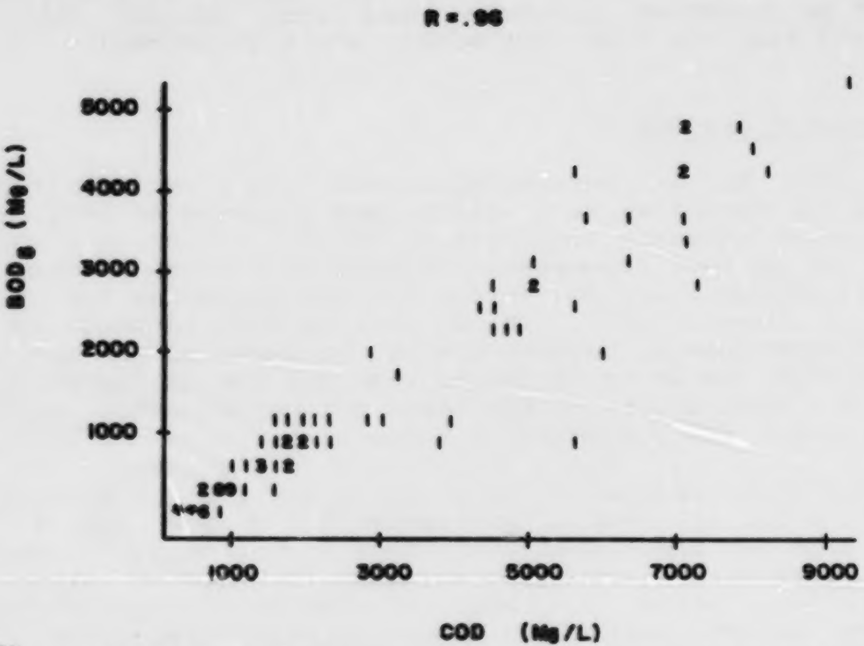

Figure 77. Finfish wastewater 5-day BOD vs. COD scatter diagram.

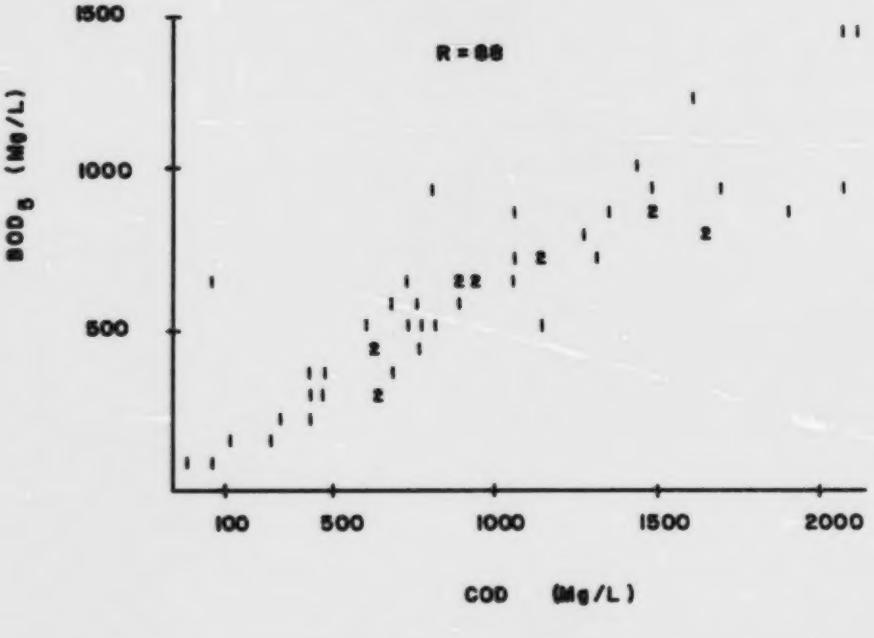

Figure 78. Shellfish wastewater 5-day BOD vs. COD scatter diagram.

the ratios estimator and the relative errors, are presented in Table 127. This analysis indicates that the 20 day BOD to 5 day BOD ratios are about the same for the wastewater from either finfish or shellfish processes and that 20 day BOD can be estimated from the 5 day BOD within about 25 percent.

### COD versus 5 day BOD

The 5 day BOD and corresponding COD data from industrial fish, finfish and shellfish wastewaters were analyzed to help determine if COD is an adequate predictor of BOD for any or all of these groups of seafood processes. Figures 75 through 78 show scatter diagrams of the 5 day BOD versus the corresponding COD for each group of commodities. It can be seen that although there is a general relationship between the two parameters, the variance of the scatter tends to be larger than for the 20 day versus 5 day BOD case. The results of the ratio estimations for each group and the total are presented in Table 128.

This analysis indicates that the 5 day BOD/COD ratio averages about 0.52 for all seafood wastewater but varies from a low of about 0.38 for industrial fish, to a high of 0.66 for shellfish. The relative errors are also estimated to be quite large except for finfish, which is about 21 percent. The rather large relative errors indicate that, except for the finfish commodities, the COD is only a moderately good predictor of 5 day BOD.

Table 127. 20-day BOD/5-day BOD ratio estimation for finfish and shellfish wastewater.

| Wastewater Source | Number of Samples | Correlation Coefficient | $\frac{\text{BOD-20}}{\text{BOD-5}}$ | Relative Error |
|---|---|---|---|---|
| Finfish | 70 | 0.98 | 1.7 | 22% |
| Shellfish | 20 | 0.92 | 1.6 | 27% |

Table 128. 5-day BOD/COD ratio estimation for industrial fish, finfish and shellfish wastewater.

| Wastewater Source | Number of Samples | Correlation Coefficient | $\frac{\text{BOD-5}}{\text{COD}}$ | Relative Error |
|---|---|---|---|---|
| Industrial | 64 | 0.83 | 0.38 | 52% |
| Finfish | 110 | 0.96 | 0.55 | 21% |
| Shellfish | 51 | 0.88 | 0.66 | 61% |
| All Seafood | 225 | 0.97 | 0.52 | 48% |

# SECTION VII

# CONTROL AND TREATMENT TECHNOLOGY

## IN-PLANT CONTROL TECHNIQUES AND PROCESSES

There are several incentives for in-plant control of seafood processing wastes: decrease operating costs, decrease wastewater and solids, improve raw material utilization, develop new products and enhance responsibility to the public.

Processing plants can usually realize savings in end-of-pipe treatment costs or in sewer costs if the in-plant change, through either reduced usage or recycling, decreases the amount of processing water required in the plant. A decrease in water usage may also decrease the waste loads in terms of BOD and suspended solids per unit of production.

Much of the waste currently being discarded as solid or lost in the plant effluent can be processed or reclaimed in an acceptable manner. For example, ten years ago salmon eggs, which account for about five percent of the total weight of the fish, presented a waste disposal problem. Today the Japanese are paying as much as $6.00 per kg ($2.70 per lb) for salmon eggs to be used for caviar.

Many seafood companies are now taking advantage of in-plant changes to increase their usable raw materials. Other companies, producing the same primary products, may be losing a potential source of income while being very concerned about how to comply with the forthcoming restrictions in the quality of effluent discharge from their plants.

### Recovery of Secondary Products

From an economic standpoint, by-product recovery offers the most potential for cost saving and profitability through marketing higher percentages of the raw material and, at the same time, reduce pollution. The following by-product recovery discussion outlines several of the major developments which are currently in use, ready for use, or will be available in the next few years.

Meat, fish and fowl are commonly placed in the category of "animal proteins" because they all have the essential amino acid balance required for good nutrition. Meats from these creatures, regardless of origin, have similar nutritional properties containing 15 to 20 percent protein. Some typical compositions of fish and shellfish are shown in Table 129. Although some of the values (i.e.: fat content of migrating fish or changing biological status) vary during the year or season, it can be seen that there is a fairly uniform composition of protein.

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Table 123. Typical composition of fish and shellfish (portion normally utilized).

| Item | Protein (%) | Fat (%) | CHO (%) | Moisture (%) | Ash (%) |
|---|---|---|---|---|---|
| Menhaden | 18.7 | 10.2 | 0 | 67.9 | 3.8 |
| Anchovy | 15-20 | 5-15 | 0 | -- | -- |
| Herring | 17.4 | 2-11 | 0 | 70.0 | 2.1 |
| Oysters | 8-11 | 2.0 | 3-6 | 79-85 | 1.8 |
| Sole | 16.7 | 0.8 | 0 | 81.3 | 1.2 |
| Rockfish | 18.9 | 1.8 | 0 | 78.9 | 1.2 |
| Cod | 17.6 | 0.3 | 0 | 81.2 | 1.2 |
| Salmon | 19-22 | 13-15 | 0 | 64.0 | 1.4 |
| Catfish | 17.6 | 3.1 | 0 | 78.0 | 1.3 |
| Tuna | 25.2 | 4.1 | 0 | 70.5 | 1.3 |
| Clams (meat only) | 14.0 | 1.9 | 1.3 | 80.8 | 2.0 |
| Crab | 17.3 | 1.9 | 0.5 | 78.5 | 1.8 |
| Halibut | 20.9 | 1.2 | 0 | 76.5 | 1.4 |
| Shrimp | 18.1 | 0.8 | 1.5 | 78.2 | 1.4 |

Fish flesh is not only highly desirable as a completely balanced protein food, but the lipids consist of mostly polyunsaturated fatty acids. These lipids have been shown to be most beneficial in limiting certain health problems that are associated with the saturated fats found in all other animals. Unfortunately, the desirable unsaturated lipids tend to oxidize quite rapidly, resulting in unacceptable flavors. This problem is minimized in the portions normally sold for human consumption but must be considered in changing processes to utilize the remaining portion for new foods.

Hence, new products being prepared from currently discarded portions (secondary raw materials) must be handled rapidly so that excess degradation does not occur prior to processing. This means that the normal procedure of allowing these portions to accumulate while the more desirable portions are being processed must be changed to insure high quality products.

One method for utilizing whole industrial fish or fish trimmings is to remove the lipid and water fractions to obtain a high protein dried "flour" that can be used for supplementing diets deficient in protein. The principal difference between this type of product and conventional fish meal is that the oil is removed to the point whereby the product is not objectionable to the consumer.

The production of concentrated fish protein has many advantages where an animal protein supplementation is desired: 1) the product can be sold in competition with other concentrated animal proteins on a protein unit basis; 2) removal of water and lipid stabilizes the product so that it can be stored indefinitely under many different climatic conditions; 3) many populations of fishes now being passed over can be diverted into human food.

Although most discussions regarding the utilization of concentrated fish proteins as food additives center around their use in developing countries, it is predicted that there will be a tremendous need for such products in the United States. By 1980, of approximately one billion kg (2.25 billion lbs) of protein additives used in the United States, 0.86 billion kg (1.9 billion lbs) will come from proteins other than meat and milk (31). Fish will undoubtedly play a most important role in filling these future requirements. The first part of this seafood study (Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Catfish, Crab, Shrimp, and Tuna Segment of the Canned and Preserved Seafood Point Source Category, June 1974) discussed several protein recovery processes.

Low protein-high mineral meals are currently produced and used in animal feed. This product can also be produced at plants that remove essentially all of the edible meat from the bones and carcasses for either food products or food additives. Crustacean meal is especially desirable for fish diets since the pigment imparts a pink color to the flesh of captive grown fish, increasing their market appeal.

The shell in several types of shellfish, particularly crab and shrimp, has a chemical composition containing materials that have potential as non-edible products for many phases of commerce. Shells from crustacea, depending on species and time of year, contain 25 to 40 percent protein, 40 to 50 percent calcium carbonate, and 15 to 25 percent chitin. Chitin is an insoluble polysaccharide that serves as the "binder" in the shell. Chitin, or the deacetylated form, chitosan, has many outstanding properties for use in flocculating, emulsifying, thickening, coagulating, improving wet strength of paper, and many other uses. The protein that can be reclaimed from the shell is high quality and does not exhibit the amine odor found in fish flesh. The first part of this study, which included crab and shrimp, discusses the process and costs for producing chitin and chitosan from shellfish waste. There is currently one commercial producer of chitin and chitosan in the United States.

## Recovery of dissolved and suspended nutrients

As stated earlier, 5 to 20 percent of the fish solids are lost in the wastewaters as dissolved and suspended particles. Recovery of these nutrients can offset the cost of recovery, and also reduce significantly the higher costs of waste treatment facilities. Pilot plant data have demonstrated economic feasibility of recovery by screening and coagulation with various chemicals.

### Recovery by Screening

Screens are available in various configurations such as vibratory disk, rotary drum, and tangential screens. A complete discussion of screens is presented later in the end-of-pipe treatment portion of this section. Table 130 shows the percent recovery obtained during this study by use of a 20-mesh Tyler screen. It should be noted that these results were not from full scale operations. Recovery from the few existing pilot or fullscale screen systems are discussed later in this section. It can be seen that for some processes a relatively large portion of the raw product can be recovered from the wastewater by screening.

### Recovery by Coagulation

A large number of chemicals, such as sodium lignosulfonate, hexametaphosphate, lime, alum, glucose trisulfate, and several polyelectrolytes, are effective in complexing and coagulating proteins from fish processing wastewaters. The coagulated proteins are removed by sedimentation or by flotation. Some of the results with hexametaphosphate and sodium lignosulfonate

Table 130. Recovery using 20-mesh screen for various seafood commodities.

| Commodity | Total Suspended Solids % Screen Recovery | % of Raw Product Recoverable |
|---|---|---|
| Salmon canning | 47 | 18 |
| Fresh/frozen salmon | 45 | .8 |
| Bottom fish | 58 | 6.0 |
| Sardines | 4 | 0.13 |
| Herring filleting | 25 | 3.7 |
| Jack mackerel | 90 | 13 |
| Clams (mechanized) | 45 | 1.4 |

Table 131. Recovery of proteins with hexametaphosphate

| Characteristics | Influent | Effluent | % Removal |
|---|---|---|---|
| Total solids mg/l | 47,800 | 21,450 | 55.0 |
| Total organic nitrogen, mg/l | 4245 | 1628 | 63.2 |
| Protein nitrogen mg/l | 4185 | 690 | 83.5 |
| Chemical oxygen demand, mg/l | 69,150 | 12,250 | 82.5 |

Table 132. Coagulation of proteins with SLS

| Characteristics | Influent | Effluent | % Removal |
|---|---|---|---|
| Total solids mg/l | 50,530 | 41,900 | 17.0 |
| Suspended solids mg/l | 25,900 | 11,370 | 56.0 |
| Chlorides, mg/l | 15,000 | 14,800 | 1.3 |
| Total organic nitrogen, mg/l | 2585 | 1525 | 41.0 |
| Protein nitrogen mg/l | 2115 | 903 | 57.3 |
| COD, mg/l | 34,600 | 12,150 | 65.0 |

(SLS) are shown in Tables 131 and 132, respectively. Actual design of the system will depend on the individual plant. Amount of protein in the recovered dried product ranges from 35 to 75 percent with the rest being fat and some minerals. Depending on the effluent, generally two to eight tons of dried material is recovered from each million gallons of effluent. Practical feeding trials on poultry have demonstrated that protein concentrate materials can replace equal weights of herring and soya meal proteins without significant change in live weight gain, feed conversion, and mortality. A plant capable of treating 45,000 l (10,000 gal.) per hour would cost in the order of $80,000 for the equipment. In round terms, protein for feed is worth normally $80 to $100/ton (not considering the present high prices for feed). For consideration of economics, one should also take into account the subsequent reduction in surcharge or the costs for waste treatment.

It is apparent that an efficient in-plant pollution treatment requires a unified system approach. Actual modification and recovery system will depend on each individual process or process combinations. Each process stream must by analyzed thoroughly before feasible in-plant modifications can be contemplated and weighed against fresh water cost, sewer charges and surcharges, and higher costs for waste treatment facilities.

## Solids Waste Reduction

Solids currently being wasted in many plants can often be reclaimed in the form of protein foods, supplementary additives, and non-edible products, depending on the particular raw material. Solids from the following sources can be processed to yield one or more of the three basic product groups (protein foods, supplementary additives, non-edible products).

1. Carcasses, frames and trimmings from filleting operations.
2. Ground fish too small to economically fillet.
3. Trimmings and portions from butchering operation normally not included in the primary end product.
4. Whole or portions of industrial fish not suitable for human consumption.
5. Trimmings and waste portions from frozen fish, fish blocks, or other forms of seafood that are being trimmed or processed in the frozen state.
6. Frozen sawdust from sawing frozen fish into steaks or other products.
7. Fresh or frozen shrimp that is too small for peeling.
8. Fresh or frozen waste portions from shrimp cleaning and peeling operations.
9. Dark meat fish that cannot be sold for fillets but that can be added to extruded products in some predetermined percentage.
10. Waste from butchering after precooking.

11. Shrimp, crab and other shell containing meat after the primary extraction process.
12. Combined solids removed from plant effluent streams after screening.
13. Solids reclaimed from effluent streams by flocculation, precipitation or other techniques.
14. Crab and shrimp shell residual from processing operations.

The production of supplementary additives using reduction processes and the production of non-edible products, such as chitin, were discussed in the first part of this study (EPA publication No. EPA-440/1-74-020-a, June 1974). The following part of this section will discuss the relatively new methods available for producing marketable protein foods.

## Raw Materials for Protein Foods

Machines are now available that remove edible meat from most any carcass, waste portion or shell waste. These machines are currently utilized in several bottom fish processing facilities. The potential products include formed patties, pressed and cleaved frozen formed fillets, specialty hors d'oeuvre items, and specialty products, the number of which is only limited by the ingenuity of the processor. The wide variety of batter and breading materials adds even further to the array of products possible.

A complete processing facility for producing protein foods includes space for filleting and a complete line for deboning, mixing, extruding, pressing blocks, power cleaving and battering and breading. The accessory facilities include equipment for mixing and handling batter and breading as well as components that are to be mixed with extruded fish for special flavored or textured products.

### Deboning

A deboning facility is capable of removing more than 90 percent of the edible flesh from most frames, whole fish, fish waste, and trimmings. Several machines are available on the market that work on the principle of forcing the meat through a perforated plate while allowing the bone or any hard cartilage, including skin, to pass through. Normal fillet waste, trimmings, etc. can be deboned directly while larger fish and parts from trimming (i.e., halibut, dogfish) should be preground prior to deboning.

Meat extruded by the deboning process is flaky in appearance and feel and is an excellent material for further extruding or forming in marketable products. Fish flesh prepared in this manner has high binding characteristics and does not require special binders to be added prior to extruding. However, various additives can be mixed into the meat to give custom flavors.

### Pressing and Cleaving

Deboned meat can be prepared in several manners. Quite often extruded patties, which are ideal for sandwiches, do not have the desired appearance or consistancy for main course items in restaurants. One method of preparing artificial fillets involves feezing the deboned meat prior to forming.

### Extruding

Many different extruder machines and forming attachments are available in a wide price range. Production machines range from single to multiple head with extruded items ranging from round and square patties to fish balls and other items.

### Battering and Breading

The major volume of breaded fish products being prepared at the present time is from fish sticks and shrimp or pawns. The large producers of these items are primarily finished processors and do not have their own source of supply. Hence, the raw materials are being pre-prepared in blocks or as IQF items.

### Economics

Section VIII discusses the capital investment required for a deboning, extruding, pressing and cleaving, batter and breading, and IQF freezer for a plant capable of processing 1200 to 1500 lbs of product per hour.

The total capital investment, $261,100, shown in Section VIII, is based on a company having no portions of the equipment necessary and must, with the exception of the basic building and utilities, design and construct the entire facility. In most plants many of the items are available. For example, a company processing fillets or similar items would probably have a freezer that could be run extra shifts if necessary to handle an increased load due to the new line. Also, many plants will have a batter and breading line. Therefore, the figures presented should be used only as a guideline in preparing the company plans for in-plant changes.

## Wastewater Flow and Pollution Load Reduction

The seafood industry uses large quantities of water (500-33,000 gals/ton of raw product processed) for various processing operations. Wastewaters originate from ice or refrigerated sea water (bilge water) on board the fishing vessel; from unloading and fluming of the fish (bailwater); from butchering and filleting operations where water is required to flow continuously over the cutting knives and conveyor belts; from thawing, precooking, can washing and cooling; retorting; washing down; and from various other unit operations. Data collected during this study indicated that the water use per ton of production was quite variable for some commodities and that up to about 38 percent of total fresh raw material weight processed was discarded in the processing wastewaters.

The suspended solids loads generally increase as the water use increases (for a certain type of process). The more water that is in contact with the product, the greater the possibility of entraining pieces of the product. Therefore, a general reduction in the use of water is usually the most effective first step in a pollution abatement program. This can be accomplished by reducing the flow of water into certain unit operations of the process and/or by recycling or reusing certain flows with or without some treatment. Further steps which can be taken are: change or optimize the process design to minimize or eliminate certain flows and waste loads, and to recover dissolved and suspended protein and oil as valuable by-products.

## Reducing the use of water in general

Increasing workers' awareness of the cost of water supply and wastewater treatment is a basic step in a good water management system. The workers often do not know how much water they are using and, in some cases, why they are using it. Water use could be minimized by common sense techniques like turning off faucets and hoses when not in use, or by using spring-loaded hose nozzles, by using high-pressure low-volume water supply systems, by using dry clean-up in-plant prior to washdown, etc. It remains to the plant personnel to determine the optimum water uses for operations like fish washing, filleting, descaling, peeling, etc., while still maintaining good final quality of the product. The coefficient of variation (ratio of standard deviation to the mean) for the various seafood commodities was often quite high. Large variation in water usage for the same operation among different plants indicate that there is plenty of room for the reduction of water usage without adversely affecting the quality. Mechanized processes were, in general, found to use considerably more water and produce greater waste loads. Since mechanization is the only way in some cases to utilize the resource efficiently or to compete with other food production operations, improvement in the design of machines is indicated. Thorough survey and metering of water flows will show that one or two operations may be using considerably more water than the rest of the operations. Efficient handling of these streams will give significant reductions for the total flow. Similarly, the individual streams with major pollution load should also be singled out. While reduction in water use will tend to increase the concentration of pollution, dry clean-up and recovery of solids will reduce this effect. In addition, concentrated effluent streams will increase the economic feasibility of nutrient recovery, and reduction in total flow will reduce capital cost on an end-of-pipe treatment system.

## Water Reduction Through Dry Solids Transportation

Much of the water used within the plant serves mainly as a collection or transport medium whether of food product or of waste solids. Oils and solid particles become entrained in this medium, enter the waste stream and must eventually be recovered. By incorporating another means of transport, such as pneumatic, a significant reduction in water use could be realized. Pneumatic systems are especially adaptable to collecting waste solids during butchering and cleanup requiring only a minimal amount of water to clean the system. Dry vacuum systems for unloading fish from boat holds without the use of bailwater are also available.

Figure 79 shows a dry solids recovery system which can be used to collect solids from butchering or inspection tables and from the clean-up operation. Collection hoppers are located under each processing table which eliminates waste fluming and spillage from collection bins which increases the clean-up waste loads. Another advantage is in the rapid collection and transport of waste solids which facilitate further processing into a marketable by-product. Otherwise, it may have been rendered unusable by lengthy detention times in collection bins or by contact with the waste stream.

The use of pneumatic floor brooms and nozzles would greatly reduce the amount of water that is necessary to maintain sanitary conditions. Water would no longer be used to flush large solids into collection drains, but rather only to rinse the smaller particles not amenable to pneumatic collection from the equipment, tables, and floors.

Rapid, waterless unloading of fish from boat holds can also be accomplished with pneumatic unloading systems. The system, shown on Figure 80, can replace many existing fish pump systems which utilize bailwater. Bailwater contains a high concentration of oils and solids and constitutes a serious treatment problem where solubles evaporation facilities are not available. The unloader may also be integrated into a dry transport system which eliminates fluming of the fish from the docks, another major source of wastewater.

Recycling or reuse

At this point, a distinction between recycling and reuse should be made. Recycling refers to using treated water in the same application for which it was previously used, while reuse can include other applications where water quality is less critical. Multiple use of water implies its use more than once, but each time for a different purpose; for example, the countercurrent use of water for successively dirtier applications.

Recycle or reuse can be the key to effective reduction in total wastewater flow and pollution load, with nominal costs involved. Often only minimal alterations in the present plant design are required to segregate and collect individual streams which can be recycled or reused for some other purpose. In case of recycling,

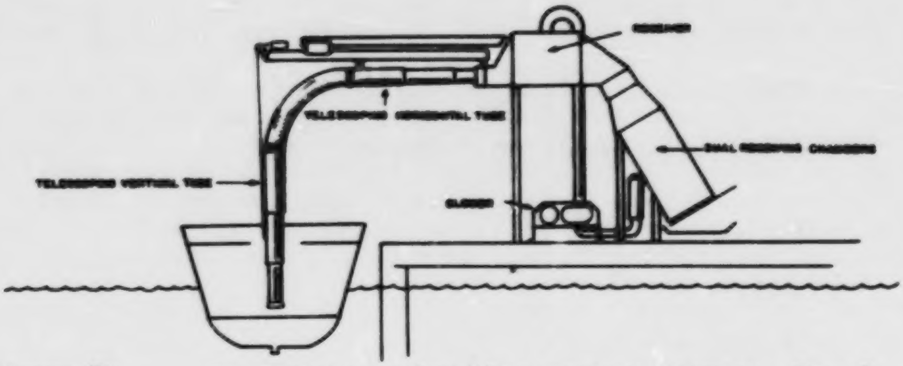

RECEIVER
TELESCOPING HORIZONTAL TUBE
DUAL RECEIVING CHAMBERS
TELESCOPING VERTICAL TUBE
BLOWER

Figure 79, Pneumatic unloading system (Temco, Inc.).

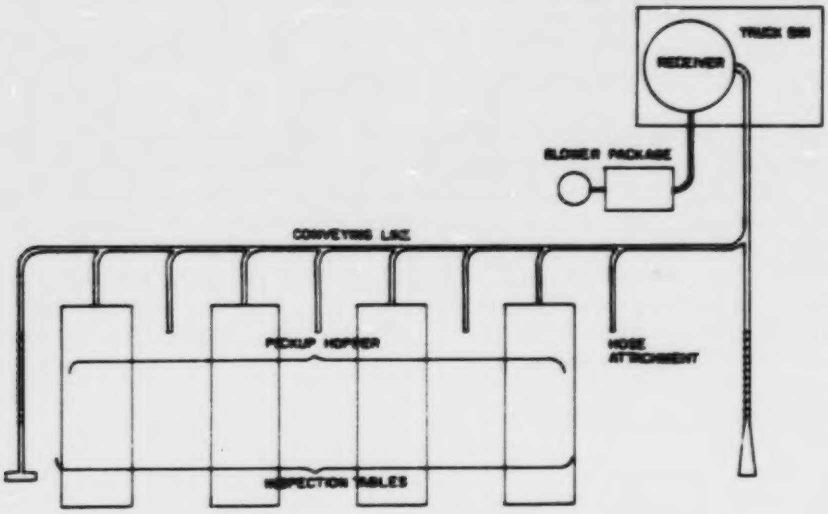

TRUCK BIN
RECEIVER
BLOWER PACKAGE
CONVEYING LINE
PICKUP HOPPER
HOSE ATTACHMENT
INSPECTION TABLES

Figure 80. Schematic drawing of in-plant dry solids removal system (Temco, Inc.).

fractional removal of pollutants is desirable. Reuse of water should be made judiciously. The water to be used for the final rinse of the product should be free of a) any microorganisms of public health significance, b) any materials or compounds which could impart discoloration, off-flavor, or off-odor to the product, or otherwise adversely affect its quality.

## IN-PLANT CONTROL RELATED TO SPECIFIC PROCESSES

Some methods which can be used to reduce waste loads, through in-plant control, are discussed below for each of the processes which are considered to be major sources.

### Fish Meal Production In-Plant Control

There are three main sources of wastewater flows in the fish meal production industry: 1) solubles plant discharge, 2) bailwater discharge, and 3) stickwater discharge. Other sources which are of lesser importance are washwater and air scrubber water.

### Solubles Plant Discharge

The primary discharge from the solubles plant is the barometric drop leg water which is used to draw a vacuum on the condenser. The average flow is about 31,000 l/kkg (7400 gal./ton) and the average BOD load is about 3 kg/kkg (6 lbs/ton).

Wastes can enter the evaporator discharge through leaks in the evaporator bodies, through boiling over into condensate and tailstock water and through vapor entrainment. Leaks and boiling over should be controlled by inspection, proper maintenance, and proper operation of the evaporator such that the process is as continuous as possible. The batch method of evaporation, which concentrates the liquid to 50 percent solids and then dumps the entire contents to solubles storage, causes the pressures, temperatures, and flow rates from each body to be in a constant state of flux. This greatly increases the probability of boil over and spillage and operation of this equipment should be supervised closely.

### Bailwater

The bailwater used to unload the fish from the hold of the boat consists of relatively large amounts of water and has a relatively high waste load as shown in Table 133.

The most acceptable method of controlling the bailwater waste flow is recycling and evaporation. This has the advantage of yielding a useful by-product (solubles) while controlling wastes. Bailwater storage capacity is required to even the flow to the plant. The cost of evaporation can be reduced by recycling the bailwater after it is separated from the fish in the plant. Recycling is limited by the accumulation of fish solids and oil, which results in pump overloading. The rate of accumulation of solids and oil can be reduced by treating the bailwater before recycling. Two methods of treatment which can be used are centrifuge and air flotation. The solids from the treatment can be added to the process stream before the cooker or pumped to the solubles plant to be evaporated. A demonstration program using a dissolved air system for bailwater treatment is described in the treatment portion of this section.

## Stickwater

Stickwater, which remains after the oil is separated from the press liquor, represents a very high waste load. Typical characteristics are shown in Table 134.

Stickwater should be controlled by evaporation or barged to sea. In-plant control of this waste source is especially important since studies show that end-of-pipe treatment of stickwater is particularly difficult. A study on alewife reduction stickwater showed 65 percent removal of COD using chemical additions, however, the final concentration was still 29,000 mg/l. The detention time in an aeration basin required to provide a final effluent of 250 mg/l COD was estimated to be 26 days (Quigley, et al. 1972).

## Salmon Processing In-Plant Control

Whether salmon is canned, frozen, dried, smoked or otherwise prepared for specialty items, the major loss of solids occurs during the butchering process. Other major sources of wastewater are thawing and fluming.

Most salmon are processed in the fresh condition. However, during periods of heavy harvesting or in remote areas not having processing facilities, the whole fish are often frozen and then transported by boat or van to areas that have the handling and processing plants. Salmon are sometimes gutted prior to freezing in order to prevent deterioration caused by the viscera being in contact with the belly wall during freezing and during long term cold storage. A salmon, however, if frozen rapidly, adequately glazed and then stored and frozen under proper conditions, can be a high quality product.

The thaw tank water at one plant sampled contributed about 30 percent of the total flow. The solids and BOD loads, however, were only about 6 percent of the total. The fish being thawed in this case were whole and had not been deteriorated by spoilage. Fish which have been gutted prior to freezing can lose a significant amount of solids due to washing out and leaching. This can be reduced by cleaning the fish more thoroughly before freezing. Using spray or air thawing can reduce the water use in this area; however, care must be taken to prevent lowering the quality of the flesh.

Table 133 Typical fish meal process bailwater characteristics.

| Parameter | Average Value Per Unit Production |
|---|---|
| Flow ratio | 210 l/kkg (50 gal./ton) |
| 5 day BOD | 8 kg/kkg (16 lb/ton) |
| Suspended solids | 5 kg/kkg (10 lb/ton) |
| Grease and oil | 3 kg/kkg (6 lb/ton) |

Table 134 Fish meal stickwater characteristics.

| Parameter | Average Value Per Unit Production |
|---|---|
| Flow ratio | 850 l/kkg (200 gal./ton) |
| 5 day BOD | 65 kg/kkg (130 lbs/ton) |
| Suspended solids | 55 kg/kkg (110 lbs/ton) |
| Grease and oil | 25 kg/kkg (50 lbs/ton) |

Dissolved and suspended solids are lost in the holding bins prior to processing. The amounts are dependent on the quality of fish, the depth of fish, and the length of time held.

Flumes used to carry fish from holding bins to the butchering machines can use a relatively large amount of water. One plant sampled in Alaska used about 1100 l/kkg (260 gal./ton). The waste loads were relatively low. Implimentation of a dry conveyance system would be offset by savings in water treatment costs.

Salmon are butchered either by hand or mechanically. The solid waste consists of the viscera, and depending on the type of dressing, head, collar, fins, tail, and organs. The actual amount of the fish removed varies tremendously for the various operations. For example, fish being prepared for the fresh or frozen market usually have the offal and head removed but seldom the collar and fins. Fish being prepared for canning have the collars, tails and fins removed. The solid portion removed during butchering ranges from 10 to 35 percent. The flows from the butchering machine were about 40 percent of the total effluent and contributed about 75 percent of the waste load. Salmon should be processed through the butchering machine at near the optimum rate since the water flow is independent of the production rate for each machine.

Cannery butchered fish are hand or mechanically cut into steaks that fit into the designated can size. The only solid loss at this point is the meat that is extruded around the knives or dropped on the floor during processing. This meat should be cleaned up prior to washdowns.

There is quite frequently a loss of solids due to the mechanical filling machines' extruding or dropping meat. The larger pieces are usually used to "patch cans" while the extruded portion becomes waste and is quite often washed out in the clean-up water.

Salmon are steaked or filleted for many different processes. Steaking operations leave little waste since the entire carcass is used. However, there is an appreciable solid residue during filleting operations since the backbone is removed. There is a signigicant percent of usable meat that can be removed from the backbone and used as extruded meat for patties or forming.

It has become a practice to add oil to many salmon packs. This is usually determined by a market that requires large amounts of free oil in the cans or by a desire to upgrade a pack of extremely low oil salmon. Recovered salmon heads are boiled and the oil is skimmed from the surface; the remaining portion consists of cooked meat and bone. The waste from this cooking process is very high in organic matter and should be handled separately from the other waste flows until the wastes can be recovered, treated, or trucked to a solubles plant.

## Bottom Fish and Miscellaneous Finfish In-Plant Control

Filleting of fish leaves the largest amount of waste when compared to other processes and yet is one of the simplest from the standpoint of unit operations. As previously stated, 70 percent or more of the landed fish is classified as waste from the filleting step. This waste consists of offal heads and the carcasses that can be deboned for meat recovery. Wastewater from manual filleting lines is generally minimal except when certain types of scalers are used. Some plants were observed to be operating descalers even when the fish were to be skinned later. The water flow through the descaler should also be interlocked with the motor, such that when the descaler is not operating the water flow is shut off.

The wastewater flows and loads from mechanized lines such as those used in the whiting industry can be quite large. Much of the water results from the fluming of fish from holding bins to the eviscerating line. A dry-conveying system, as used in the sardine industry, would reduce flows and loads substantially.

Halibut arrives at the plants either frozen or fresh. The offal and often the head are removed by the fishermen before delivery. Therefore, the processing scheme for halibut is rather simple and results in small amounts of waste. The fletching of halibut results in backbone and trimming waste that can be deboned and made into excellent meat products. The sawdust from sawing of frozen halibut can be processed into a high quality fish flour for human consumption.

## Herring Food Processes In-Plant Control

The wastewater flows and loads from the canning, filleting or pickling of herring can be substantial.

Most of the waste loads from the sardine canning industry come from the pumping of fish to the holding bins and/or to the packing tables and the dumping of stickwater from the precook operations. Bailwater used to transport fish to the holding bins can be recycled or pneumatic fish unloading systems, as discussed previously in this section, could be used. Flumes from the holding bins to the packing tables have been replaced at several plants with conveyor systems.

The stickwater from the precook can dumps should be collected separately for by-product recovery as this is very concentrated liquid with BOD loads of 20,000 to 50,000 mg/l.

Herring filleting produces a high waste load due to unloading water and the fluming of fish to and from the filleting machines. The filleting machines should also be maintained properly to reduce the number of mutilated fish. Ideally, herring filleting operations should be located near reduction plants which can take the large volume of carcasses generated. If this is not possible, fluming water should be reduced by dry-conveying. Bailwater should be recycled or air unloading systems can be used.

Herring pickling produces a high waste load due to the scaling, cutting and curing operations. Water used for descaling could be recycled and flumes to the cutting and filleting operations could be replaced with conveyor systems. The water from the curing vats is a small percentage of the total; however, the BOD load is high and should be handled and treated separately from the other waste flows.

## Clam or Oyster Process In-Plant Control

The largest flows and loads from the shellfish processes studied are from the mechanized surf clam operation where considerable washing of the product is performed. The washwater from operations toward the end of the process should be reused near the beginning of the process where quality control is not critical. The clam bellies constitute about seven to ten percent of the weight in the shell and should be recovered for animal food.

The flows and loads from oyster plants are less than for clam plants since the viscera is not removed during processing. The washdown water at the two steamed oyster plants investigated appeared to be abnormally high in volume and waste loads and it is believed that a substantial reduction can be made in this area.

## End-of-Pipe Control Techniques and Processes

Historically, seafood plants have been located near or over receiving waters which were considered to have adequate waste assimilative capacities. The nature of the wastes from seafood processing operations are such that they are generally readily biodegradable and do not contain substances at toxic levels. There are even several instances where the biota seem to thrive on the effluent, although there is generally a shift in the abundance of certain species. Consequently, at the time of this study most seafood processors had little, if any, waste treatment.

Increasing concern about the condition of the environment in recent years has stimulated activity in the application of existing waste treatment technologies to the seafood industry. However, to date there are few systems installed, operational data are limited and many technologies which might find application in the future are unproved. The following section describes the types of end-of-pipe control techniques which are available, and discusses case histories where each have been applied to the seafood industry on either a pilot plant or full-scale level. Several techniques or systems are closely associated with trade names. The mention of these trade name systems, however, does not constitute endorsement; they are cited for information purposes only.

## Remote Alaska Physical Treatment Alternative

Figure 81 illustrates a treatment alternative for discharge of comminuted processing wastes for the remote, isolated Alaskan seafood processor.

## Waste Solids Separation, Concentration and Disposal

Nearly all fish processors produce large volumes of solids which should be separated from the process water as quickly as possible. A study done on freshwater perch and smelt (23) shows that a two hour contact time between offal and the carriage water can increase the COD concentration as much as 170 percent and increase suspended solids and BOD about 50 percent (see Figure 82). Fish and shellfish solids in the waste streams have commercial value as by-products only if they can be collected prior to significant decomposition, economically transported to the subsequent processing location, and marketed.

Many processors have recognized the importance of immediate capture of solids in dry form. Some end-of-pipe treatment systems generate further waste solids ranging from dry ash to putrescible sludges containing 98 to 99.5 percent water. Sludges should be subjected to concentration prior to transport. The extent and method of concentration required depends on the origin of the sludge, the collection method, and the ultimate disposal operation. The descriptions which follow are divided into separation, concentration, disposal (including recycling and application to the land), and wastewater treatment.

### Separation methods

Screening and sedimentation are commonly used separation techniques employing a combination of physical chemical forces.

Screening is practiced, in varying degrees, throughout the U.S. fish and shellfish processing industries for solids recovery, where such solids have marketable value, and to prevent waste solids from entering receiving waters or municipal sewers. Screens may be classified as follows:

a. revolving drums (inclined, horizontal, and vertical axes);

b. vibrating, shaking or oscillating screens (linear or circular motion);
c. tangential screens (pressure or gravity fed);
d. inclined troughs;
e. bar screens;
f. drilled plates;
g. gratings;
h. belt screens; and
i. basket screens.

Rectangular holes or slits are correlated to mesh size either by geometry or performance data. Mesh equivalents specified by performance can result in different values for the same screen, depending on the nature of the screen feed. For example, a tangential screen with a 0.076 cm (0.030 in.) opening between bars may be called equivalent to a 40-mesh screen. The particles retained may be smaller than 0.076 cm diameter, however, because of hydrodynamic effects.

Revolving drums consist of a covered cylindrical frame with open ends. The screening surface is a perforated sheet or woven mesh. Of the three basic revolving drums, the simplest is the inclined plane (drum axis slightly inclined). Wastewater is fed into the raised end of the rotating drum. The captured solids migrate to the lower end while the liquid passes through the screening surface.

Horizontal drums usually have the bottom portion immersed in the wastewater. The retained solids are held by ribs on the inside of the drum and conveyed upward until deposited by gravity into a centerline conveyor. Backwash sprays are generally used to clean the screen. A typical horizontal drum is shown in Figure 83. F.G. Claggett (32) tested this type rotary screen using a size 34-mesh on salmon canning wastewater and also on bailwater from herring boats. The results are listed in Table 135.

Inclined and horizontal drum screens have been used successfully in several seafood industries, such as the whiting, herring filleting, and fish reduction plants.

At least one commercial screen available employs a rapidly rotating (about 200 rpm) drum with a vertical axis. The wastewater is sprayed through one portion of the cylinder from the inside. A backwash is provided in another portion of the cycle to clear the openings. Woven fabric up to 400-mesh has been used satisfactorily. This unit is called a "concentrator" since only a portion of the impinging wastewater passes through. About 70 to 80 percent of the wastewater is treated effectively, which necessitates further treatment of the concentrate. The efficacy of this, and other systems, in treating shellfish and seafood wastes have been investigated on a pilot scale in the Washington salmon industry, and the Alaskan crab and shrimp

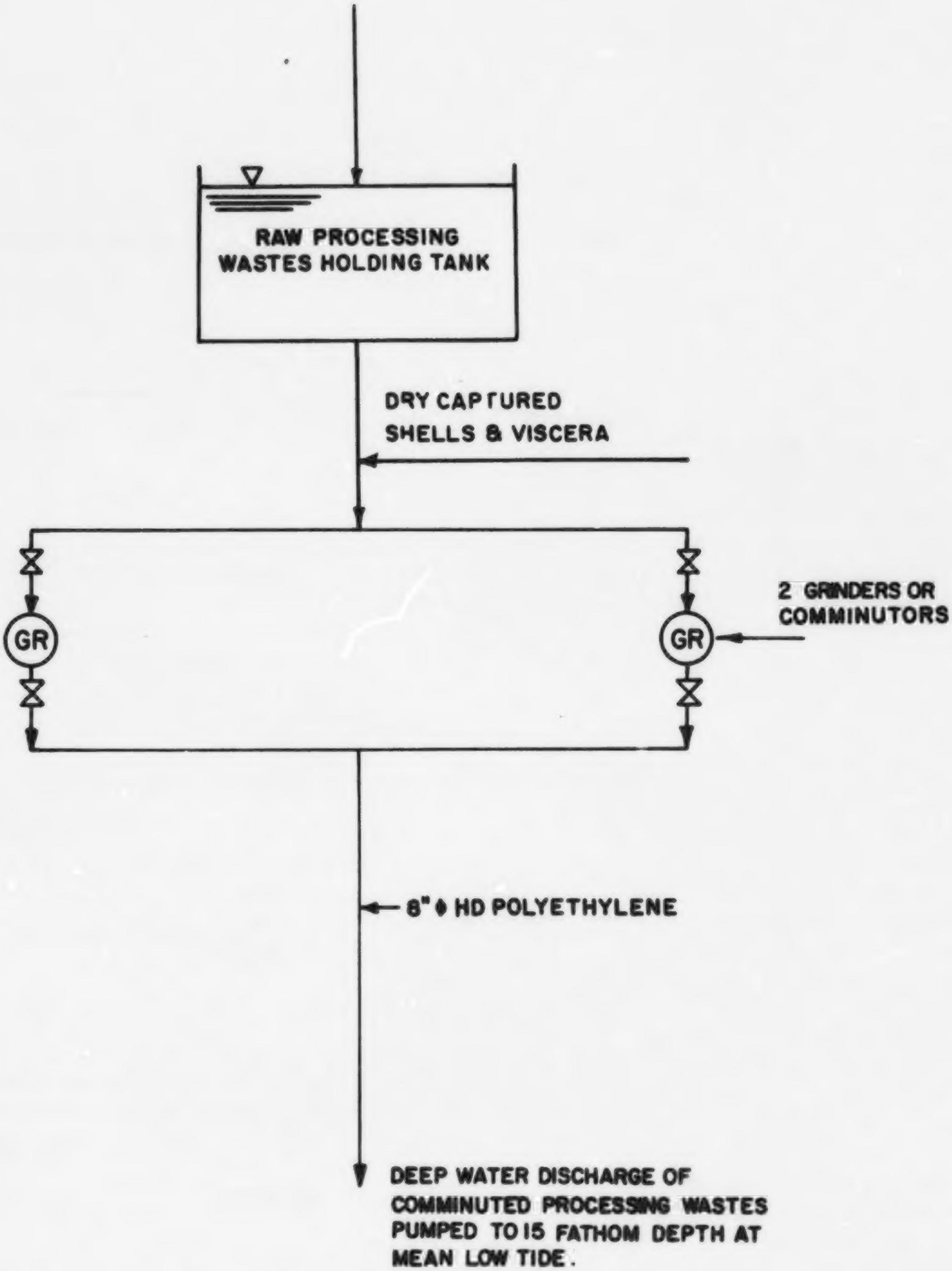

RAW PROCESSING
WASTES HOLDING TANK
DRY CAPTURED
SHELLS & VISCERA
2 GRINDERS OR
COMMINUTORS
GR
GR
8" ϕ HD POLYETHYLENE
DEEP WATER DISCHARGE OF
COMMINUTED PROCESSING WASTES
PUMPED TO 15 FATHOM DEPTH AT
MEAN LOW TIDE.

Figure 81. Alaskan physical treatment alternative, remote plants with adequate flushing available.

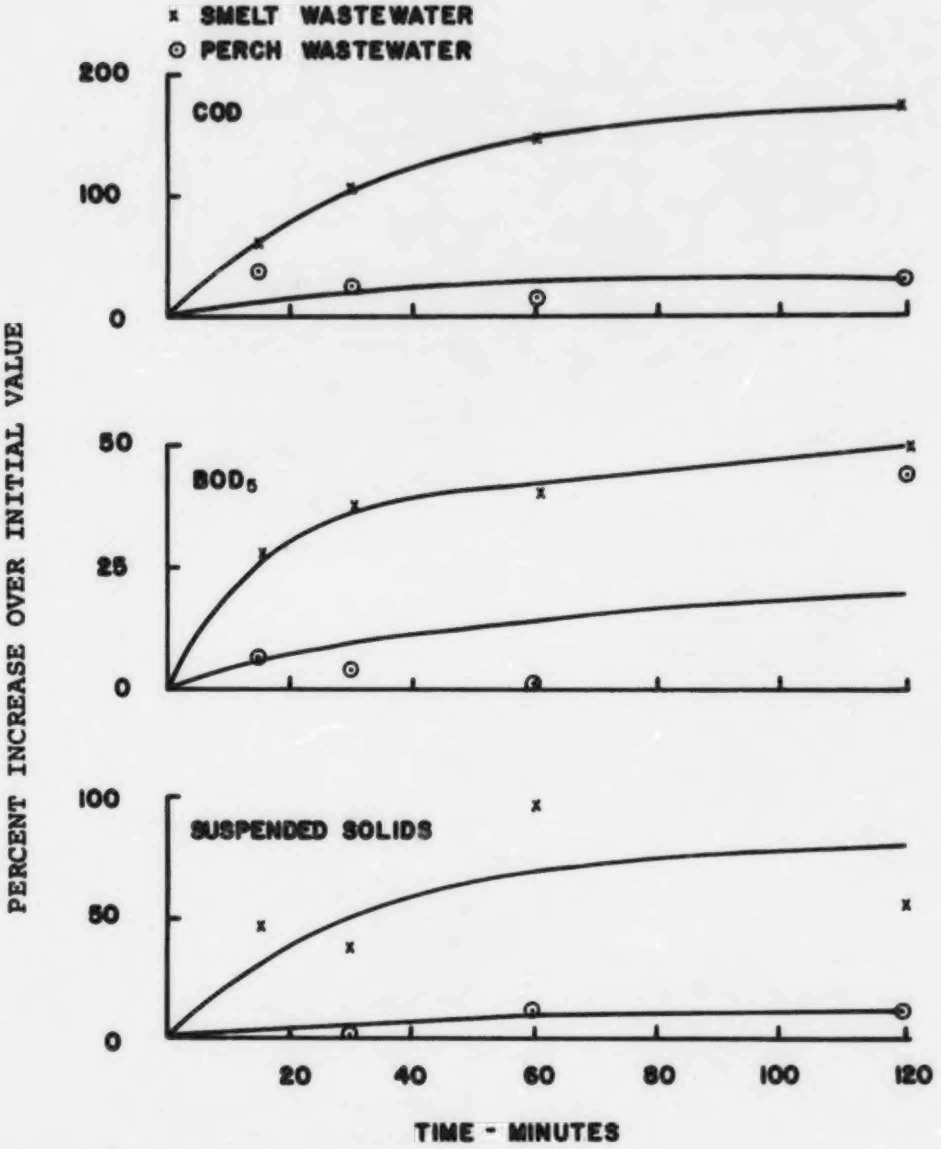


Figure 82. Increase in waste loads through prolonged contact with water. (23)

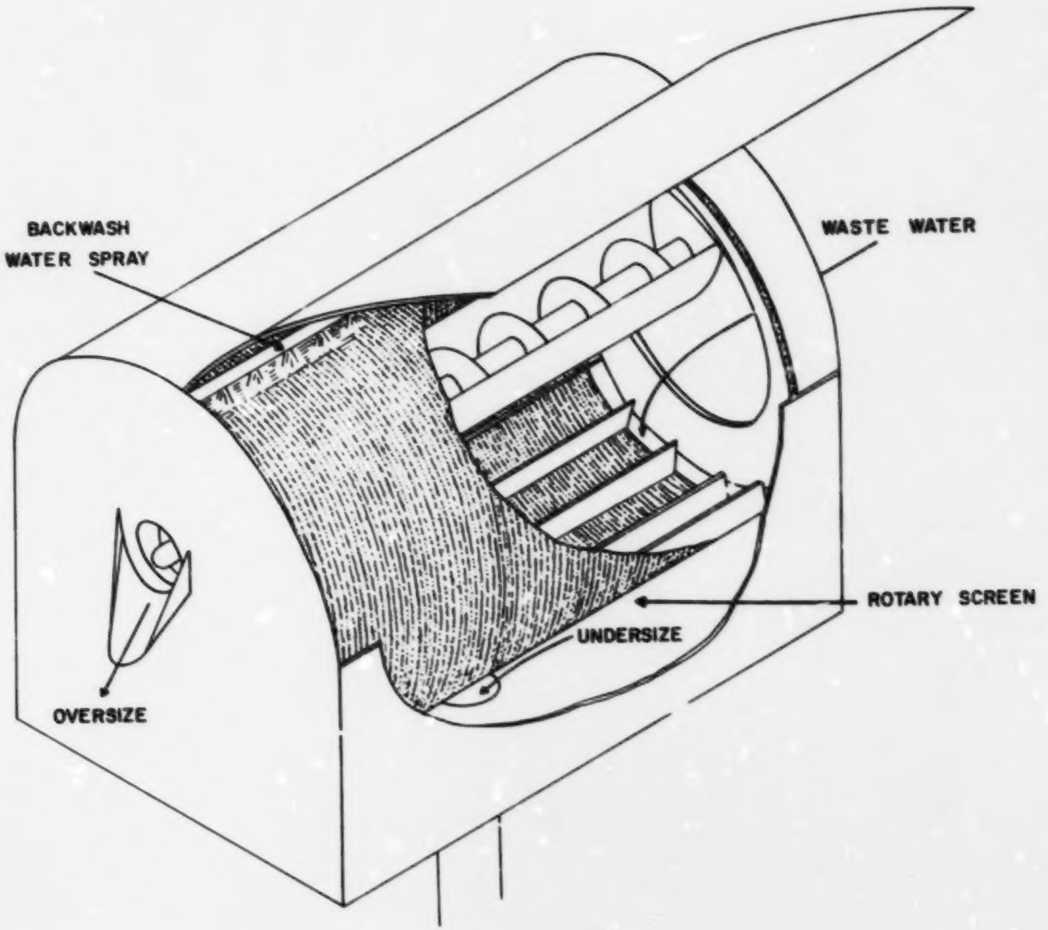

BACKWASH
WATER SPRAY
WASTE WATER
ROTARY SCREEN
UNDERSIZE
OVERSIZE

Figure 83. Typical horizontal drum rotary screen.

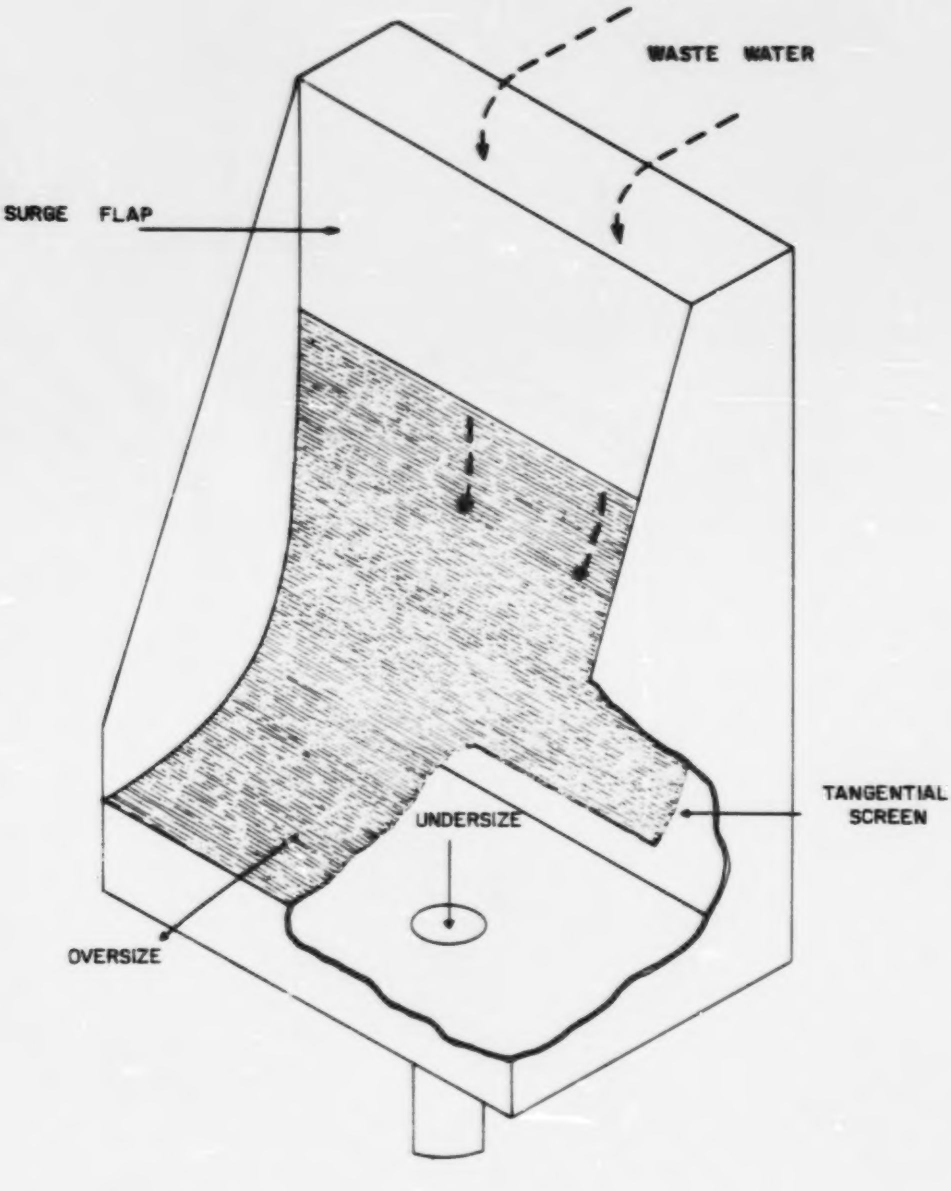

WASTE WATER
SURGE FLAP
TANGENTIAL SCREEN
UNDERSIZE
OVERSIZE

Figure 84. Typical tangential screen.

industries (33) with some success. The results of these studies are shown in Table 136.

Vibratory screens are more commonly used in the seafood industry as unit operations rather than wastewater treatment. The screen housing is supported on springs which are forced to vibrate by an eccentric. Retained solids are driven in a spiral motion on the flat screen surface for discharge at the periphery. Other vibratory-type screens impart a linear motion to retained particles by eccentrics. Blinding is a problem with vibratory screens handling seafood wastewaters. Salmon waste is difficult to screen because of its fibrous nature and high scale content. Crab butchering waste, also quite stringy, is somewhat less difficult to screen.

Table 137 shows the results of the National Canners Association study on salmon canning wastewaters which included tests using a vibrating screen. It can be seen that the removal efficiencies are lower than for the horizontal drum screen or the SWECO concentrator. The vibratory screen was also more sensitive to flow variations and the solids content of the wastewater.

Tangential screens are finding increasing acceptance because of their inherent simplicity, reliability and effectiveness. A typical tangential screen is shown in Figure 84. It consists of a series of parallel triangular or wedgeshaped bars oriented perpendicular to the direction of flow. The screen surface is usually curved and inclined about 45 to 60 degrees. Solids move down the face and fall off the bottom as the liquid passes through the openings ("Coanda effect"). No moving parts or drive mechanisms are required. The feed to the screen face is via a weir or a pressurized nozzle system impinging the wastewater tangentially on the screen face at the top. The gravity-fed units are limited to about 50 to 60-mesh (equivalent) in treating seafood wastes. Pressure-fed screens can be operated with mesh equivalents of up to 200-mesh.

Tangential screens have met with considerable acceptance in the fish and shellfish industry. They currently represent the most advanced waste treatment concept voluntarily adopted by broad segments of the industry. One reason for this wide acceptance has been the thorough testing history of the unit. Data are available (although much is proprietary) on the tangential screening of wastewaters emanating from plants processing a variety of species. A summary of some recent work appears in Table 138.

Large solids should be separated before fine screening to improve performance and prevent damage to equipment. One method is to cover floor drains with a coarse grate or drilled plate with holes approximately 0.6 cm (0.25 in.) in diameter. This coarse grate and a magnet can prevent oversize or unwanted objects such as polystyrene cups, beverage cans, rubber gloves, tools, nuts and bolts or broken machine belts from entering the treatment

Table 135 Northern sewage screen test results.

| Wastewater Source | Percentage Reduction In Total Solids (34-mesh screen) (Claggett, 1973) |
|---|---|
| Salmon canning | 57 |
| Herring bailwater | 48 |

Table 136 SWECO concentrator test results.

| Wastewater Source | Parameter | Percentage Reduction | |
|---|---|---|---|
| | | 165-mesh | 325-mesh |
| Salmon | Settleable solids | -- | 100 |
| | Suspended solids | 53 | 34 |
| | COD | 36 | 36 |
| Shrimp peeler | Settleable solids | 99 | -- |
| | Suspended solids | 73 | -- |
| | COD | 46 | -- |

Table 137 SWECO vibratory screen performance on salmon canning wastewaters

| Parameter | Percentage Reduction (40-mesh screen) |
|---|---|
| Settleable solids | 14 |
| Suspended solids | 31 |
| COD | 30 |

Table 136 . Tangential screen performance.

| Wastewater Source | Parameter | 30 mesh | Percentage Reduction<br>40 mesh | 50 mesh | 100 mesh | 150 mesh |
|---|---|---|---|---|---|---|
| Sardines (42) | SS | 26 | -- | -- | -- | -- |
| | BOD | 9 | -- | -- | -- | -- |
| Salmon | Set. solids | -- | -- | -- | 35 | 86 |
| | SS | -- | -- | -- | 15 | 36 |
| | COD | -- | -- | -- | 13 | 25 |
| Shrimp (33) | Set. solids | 88 | -- | 93 | 83 | -- |
| | SS | 46 | -- | 43 | 58 | -- |
| | COD | 21 | -- | 18 | 23 | -- |
| Salmon (33) | Set. solids | 50 | -- | -- | -- | -- |
| | SS | 56 | -- | -- | -- | -- |
| | COD | 55 | -- | -- | -- | -- |
| King Crab (33) | Set. solids | 83 | -- | -- | -- | -- |
| | SS | 62 | -- | -- | -- | -- |
| | COD | 51 | -- | -- | -- | -- |
| Salmon (34) | Total solids | -- | 56 | -- | -- | -- |
| Herring (34) | Total solids | -- | 48 | -- | -- | -- |

system. Such objects can cause serious damage to pumps and may foul the screening system.

Some salmon canneries utilize a perforated inclined trough to separate large solids from the wastewater. The wastewater is fed into the lower end and conveyed up the trough by a screw conveyer. The liquid escapes through the holes while the solids are discharged to a holding area. Inclined conveyors and mesh belts are commonly used throughout the fish and shellfish industry to transport and separate liquids from solid wastes.

A typical screening arrangement using a tangential screen is shown in Figure 85. A sump is useful in maintaining a constant wastewater feed rate to the screen. It also helps to decrease fluctuations in the wastewater solids load such as occur in batch processes. Some form of agitator may be required to keep the suspended solids in suspension. Ideally, the sump should contain a one-half hour or more storage capacity to permit repairs to downstream components. The pump used is an important consideration. Centrifugal trash pumps, of the open impeller type, are commonly used, however, this type of pump tends to pulverize solids as they pass through. During an experiment on shrimp wastes the level of settleable solids dramatically increased after screening (30-mesh screen) when the waste water was passed through a centrifugal pump (33). Positive displacement or progressing cavity non-clog pumps are recommended. Screens should be installed with the thought that auxiliary cleaning devices may be required later.

Blinding is a problem that depends, to some extent, on the type of screen employed, but to a greater extent on the nature of the waste stream. Salmon waste is particularly difficult to screen. One cannery has reduced plugging by installing mechanical brushes over the face of their tangential screen.

Many of the screen types mentioned above produce solids containing considerable excess water which must be removed either mechanically or by draining. A convenient place to locate a screen assembly is above the storage hopper so that the solids discharge directly to the hopper. However, hoppers do not permit good drainage of most stored solids. If mechanical dewatering is necessary, it may be easier to locate the screen assembly on the ground and convey dewatered solids to the hopper.

Processing wastewaters from operations in seafood plants are highly variable with respect to suspended solids concentrations and the size of particulates. On-site testing is required for optimum selection in all cases.

Some thought should be given to installing multiple screens to treat different streams separately within the process plant. Some types of screens are superior for specific wastewaters and there may be some economy in using expensive or sophisticated screens only on the hard-to-treat portions of the waste flows.

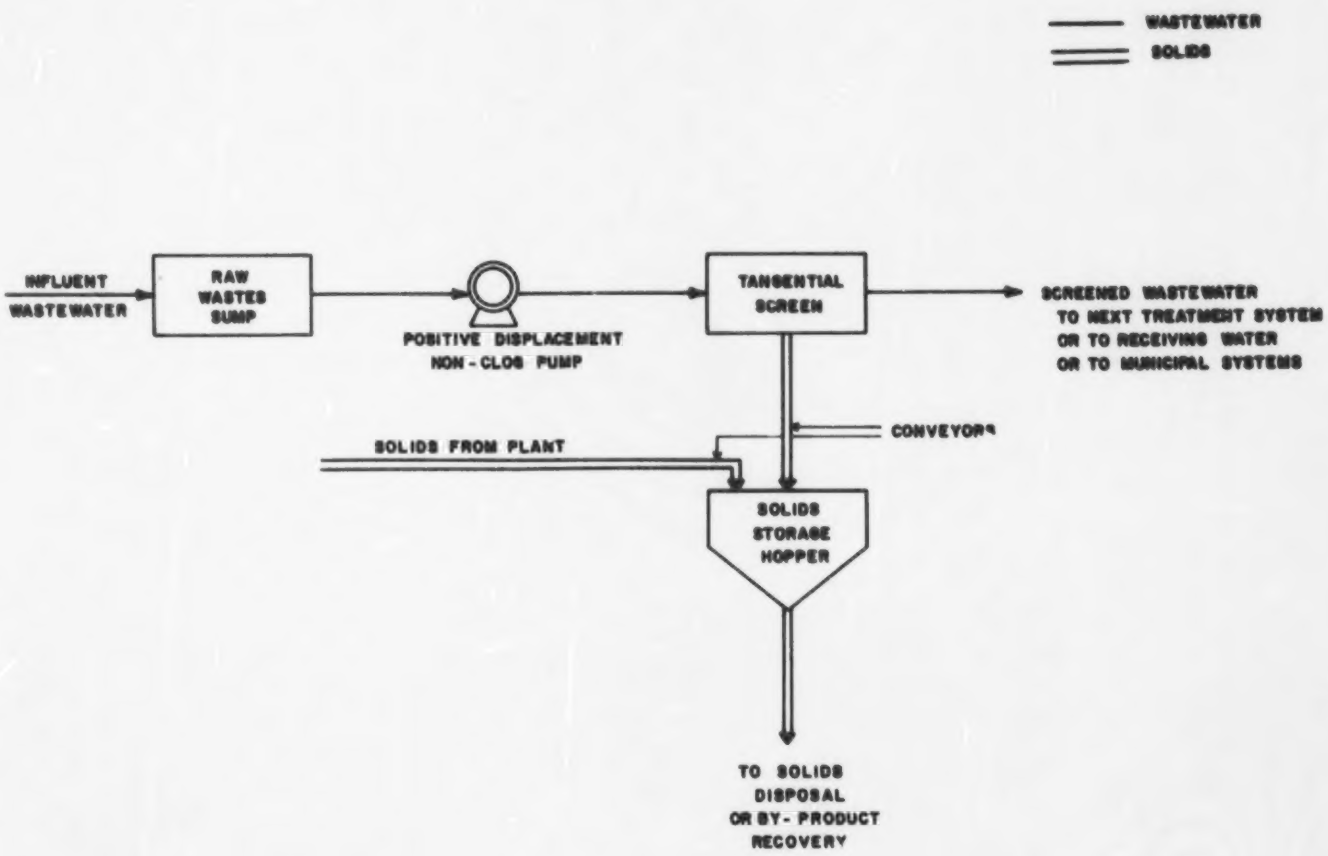

WASTEWATER
SOLIDS
INFLUENT WASTEWATER
RAW WASTES SUMP
POSITIVE DISPLACEMENT NON-CLOG PUMP
TANGENTIAL SCREEN
SCREENED WASTEWATER TO NEXT TREATMENT SYSTEM OR TO RECEIVING WATER OR TO MUNICIPAL SYSTEMS
CONVEYORS
SOLIDS FROM PLANT
SOLIDS STORAGE HOPPER
TO SOLIDS DISPOSAL OR BY-PRODUCT RECOVERY

Figure 85. Typical screen system for seafood processing operations.

Microscreens to effect solids removal from salmon wastewaters in Canada have been tried. They were found to be inferior to tangential screens for that application. Microscreens and microstrainers have not, however, been applied in the United States.

Screens of most types are relatively insensitive to discontinuous operation and flow fluctuations, and require little maintenance. The presence of salt water necessitates the use of stainless steel elements. Oil and grease accumulation can be reduced by spraying the elements with a fluorocarbon coating.

Screens of proper design are a reliable and highly efficient means of seafood waste treatment, providing the equivalent of "primary treatment." The cost of additional solids treatment, approaching 95 percent solids removal by means of progressively finer screens in series must, in final design, be balanced against the cost of treatment by other methods, including chemical coagulation and sedimentation.

## Sedimentation

Sedimentation, or settling of solids, effects solids-liquid separation by means of gravity. Nomenclature for the basins and equipment employed for this process includes terms such as grit chamber, catch basin, and clarifier, depending on the position and purpose of the particular unit in the treatment train. The design of each unit, however, is based on common considerations. These include; the vertical settling velocity of discrete particles to be removed, and the horizontal flow velocity of the liquid stream. Detention times required in the settling basins range from a few minutes for heavy shell fragments to hours for low-density suspensions. Grit chambers to remove sand and shell particles are common in the clam and oyster industries, however, the current absence of settling basins or clarifiers in the fish industries indicates the desirability of simple on-site settling rate studies to determine appropriate design parameters for liquid streams undergoing such treatment. Section V of this study presents the results of settleable solids tests, which were determined using the Imhoff cone method, for each seafood process monitored.

Removal of settled solids from sedimentation units is accomplished by drainoff, scraping, and suction-assisted scraping. Frequent removal is necessary to avoid putrefaction. Seafood processors using brines and sea water must consider the corrosive effect of salts on mechanism operation. Maintenance of reliability in such cases may require parallel units even in small installations.

Sedimentation processes can be upset by such "shock loadings" as fluctuations in flow volume, concentration and, occasionally, temperature. Aerated equalization tanks may provide needed capacity for equalizing and mixing wastewater flows. However, deposition of solids and waste degradation in the equalization tank may negate its usefulness.

Sedimentation tests run on a combined effluent from a fresh water perch and smelt plant produced an average of approximately 20 percent BOD and 9 percent suspended solids removal after a 60 minute detention time (26). The nature of most fish and shellfish wastewater require that chemical coagulants be added to sedimentation processes to induce removal of suspended colloids.

A partially successful gravity clarification system was developed using large quantities of a commercial coagulant called F-FLOK. F-FLOK is a derivative of lignosulfonic acid marketed by Georgia Pacific Corporation. In a test on salmon wastewater, reported by E. Robbins (35), the floc formed slowly but, after formation, sedimentation rates of four feet per hour were achieved. Table 139 shows the results of the test.

Properly designed and operated sedimentation units incorporating chemical coagulants can remove most particulate matter. Dissolved material, however, will require further treatment to achieve necessary removals.

It is important to note that the gravity clarifiers described above, when operated with normal detention times, may lead to strong odors due to rapid microbial action. This could also produce floating sludge.

Major disadvantages of sedimentation basins include land area requirements and structural costs. In addition, the settled solids normally require dewatering prior to ultimate disposal.

### Concentration methods

Although screenings from seafood wastewater usually do not require dewatering; sludges, floats, and skimmings from subsequent treatment steps must usually be concentrated or dried to economize storage and transport. The optimum degree of concentration and the equipment used must be determined in light of transportation costs and sludge characteristics, and must be tailored to the individual plant's location and production.

Sludges, floats, skimmings, and other slurries vary widely in dewaterability. Waste activated sludges and floated solids are particularly difficult to dewater. It is probable that most sludges produced in treating fish processing wastes will require conditioning before dewatering. Such conditioning may be accomplished by means of chemicals or heat treatment. Anaerobic digestion to stabilize sludges before dewatering is not feasible at plants employing salt waters or brines. Aerobic digestion will produce a stabilized sludge, but not one which is easy to dewater. The quantity and type of chemical treatment must be determined in light of the ultimate fate of the solids fraction. For example, lime may be deposited on the walls of condensers. Alum has been shown to be toxic to chickens at 0.12 percent concentrations, and should be used with care in sludges intended for feed byproduct recovery.

A large variety of equipment is available for sludge dewatering and concentration, each unit having particular advantages. These units include vacuum filters, filter presses, gravity-belt dewaterers, spray dryers, incinerators, centrifuges, cyclone classifiers, dual-cell gravity concentrators, multi-roll presses, spiral gravity concentrators, and screw presses. Such equipment can concentrate sludges from 0.5 percent solids to a semi-dry cake of 12 percent solids, with final pressing to a dry cake of over 30 percent solids. Units are generally sized to treat sludge flows no smaller than 38 l/min (10 gpm). Because maintenance requirements range from moderate to high, the provision of dual units is required for continuity and reliability.

In the seafood industry only fish meal plants currently use solids dewatering and concentration equipment. Smaller installations with flows under about 757 cum/day (200,000 gpd) probably cannot utilize dewatering equipment economically.

## Disposal methods

A high degree of product recovery is practiced by industries in locations where solubles and meal plants are available. The pet food, animal food and bait industries also use a considerable amount of solids from some industries. Where such facilities do not exist, alternative methods of solids disposal such as incineration, sanitary landfill and deep sea disposal must be considered.

Most fish industries have not yet tried seafood solids waste incineration. Continuous operation of multiple hearth furnaces has provided effective incineration of municipal wastes and sludges. Intermittent start-up and shut-down is inefficient and shortens the useful life of the quipment.

A molten salt bath incinerator is under development with one unit in operation. The by-products are CO2, water vapor, and a char residue skimmed from the combustion chamber. This device may prove to be viable in reasonably small units (36).

Both types of incineration waste beneficial nutrients while leaving an ash which requires ultimate disposal. Fuel costs are also high and air pollution control equipment must be installed to minimize emissions.

Sanitary landfill is most suitable for stabilized (digested) sludges and ash. In some regions, disposal of seafood waste solids in a public landfill is unlawful. Where allowed and where land is available, private landfill may be a practical method of ultimate disposal. Land application of unstablized, putrescible solids as a nutrient source may be impractical because of the nuisance conditions which may result. The application of stabilized sludges as soil conditioners may have local feasibility.

The practicality of landfill or surface land disposal is dependent on the absence of a solids reduction facility, and the presence of a suitable disposal site. The nutritive value of the solids indicates that such methods are among the least cost-efficient currently available.

In addition to placement in or on the land and dispersal in the atmosphere (after incineration), the third (and only remaining) ultimate disposal alternative is dispersion in the waters. Deep sea disposal of fish wastes can be a means of recycling nutrients to the ocean. This method of disposal does not subject the marine environment to the potential hazards of toxicity and pathogens associated with the dumping of human sewage sludges, municipal refuse and many industrial wastes. The disposal of seafood wastes in deep water or in areas subject to strong tidal flushing can be a practical and possibly beneficial method of ultimate disposal. In some locations, the entire waste flow could be ground and pumped to a dispersal site in deep water without adverse effects. The U.S. Congress recognized the unique status of seafood wastes when, in 1972, they specifically exempted fish and shellfish processing wastes from the blanket moratorium on ocean dumping contained in the so-called "Ocean Dumping Act."

Grinding and disposing of wastes in shallow, quiescent bays has been practiced in the past, but should be discontinued. Disposal depths of less than 13 m (7 fathoms), particularly in the absence of vigorous tidal flushing, may be expected to have a detrimental effect on the marine environment and the local fishery, whereas discharge into a deep site generally would not.

The identification of suitable sites for this practice undoubtedly demands good judgment and detailed knowledge of local conditions. Used in the right manner, however, deep sea disposal is an efficient and cost-effective technique, second only to direct solids recovery and by-product manufacture.

## Wastewater Treatment

Wastewater treatment technology to reduce practically any effluent to any degree of purity is available. The cost effectiveness of a specific technology depends in part on the contaminants to be removed, the level of removal required, the scale of the operation, and most importantly on local factors, including site availability and climate. Because these factors vary widely among individual plants in the fish processing industries, it is difficult to attempt to identify a technology which may prove superior to all others within an industrial subcategory.

The following general description is divided into physical-chemical and biological methods for the removal of contaminants.

## Physical-chemical treatment

Physical-chemical treatment is capable of achieving high degrees of wastewater purification in significantly smaller areas than biological methods. This space advantage is often accompanied by the expense of high equipment, chemical, power, and other operational costs. The selection of unit operations in a physical-chemical or biological-chemical treatment system cannot be isolated cost-effectively from the constraints of each plant site. The most promising treatment technologies for the industries under consideration are chemical coagulation and air flotation. There is yet little practical application for demineralization technology including reverse osmosis, electrodialysis, electrolytic treatment, and ion exchange, or for high levels of organic removal by means of carbon adsorption.

### Chemical Oxidation

Chlorine and ozone are the most promising oxidants, although chlorine dioxide, potassium permanganate, and others are capable of oxidizing organic matter found in the process wastewaters. This technology is not in common use because of economic feasibility restrictions.

Chlorine could be generated electrolytically from salt waters adjoining most processors of marine species, and utilized to oxidize the organic material and ammonia present (37). Ozone could be generated on-site and pumped into de-aerated wastewater. De-aeration is required to reduce the build-up of nitrogen and carbon dioxide in the recycle gas stream. The higher the COD, the higher the unit ozone reaction efficiency. Both oxidation systems offer the advantages of compact size. The operability of the technology with saline wastewaters, and the practicability of small units, have not been evaluated in the seafood processing industry (38).

### Air Flotation

Air flotation with appropriate chemical addition is a physical chemical treatment technology capable of removing heavy concentrations of solids, greases, oils, and dissolved organics in the form of a floating sludge. The buoyancy of released air bubbles rising through the wastewater lifts materials in suspension to the surface. These materials include substantial dissolved organics and chemical precipitates, under controlled conditions. Floated, agglomerated sludges are skimmed from the surface, collected and dewatered. Adjustment of pH to near the isoelectric point favors the removal of dissolved protein from fish processing wastewaters. Because the flotation process brings partially reduced organic and chemical compounds into contact with oxygen in the air bubbles, satisfaction of immediate oxygen demand is a benefit of the process in operation. Present flotation equipment consists of three types of systems for wastewater treatment: 1) vacuum flotation; 2) dispersed air flotation; and 3) dissolved air flotation.

1. Vacuum flotation: In this system, the waste is first aerated, either directly in an aeration tank or by permitting air to enter on the suction side of a pump. Aeration periods are brief, some as short at 30 seconds, and require only about 185 to 370 cc/l (0.025 to 0.05 cu ft/gal) of air (39). A partial vacuum of about 0.02 atm (9 in. of water) is applied, which releases some air as minute bubbles. The bubbles and attached solids rise to the surface to form a scum blanket which is removed by a skimming mechanism. A disadvantage is the expensive air-tight structure needed to maintain the vacuum. Any leakage from the atmosphere adversely affects performance.

2. Dispersed air flotation: Air bubbles are generated in this process by the mechanical shear of propellers, through diffusers, or by homogenization of gas and liquid streams. The results of a pilot study on tuna wastewater are shown in Table 140 and indicate that a dispersed air flotation system could be successful. The unit was a WEMCO HydroCleaner with five to 10 minute detention time. The average percent reduction of five-day BOD, grease and oil, and suspended solids was estimated using two types of chemical additives. Each run consisted of one hour steady state operation with flow proportioned samples taken every five minutes. It should be noted that the average of five runs with different chemical additions are presented rather than the optimum.

3. Dissolved air flotation: The dissolved air can be introduced by one of the methods: 1) total flow pressurization; 2) partial flow pressurization; or 3) recycle pressurization. In this process, the wastewater or a recycled stream is pressurized to 3.0 to 4.4 atm (30 to 50 psi) in the presence of air and then released into the flotation tank which is at ambient pressure. In recycle pressurization the recycle stream is held in the pressure unit for about one minute before being mixed with the unpressurized main stream just before entering the flotation tank.

The flotation system of choice depends on the characteristics of the waste and the necessary removal efficiencies. Mayo (40) found use of the recycle gave best results for industrial waste and had lower power requirements. Recycling flows can be

Table 139 . Gravity clarification using F-FLOK coagulant (35)

| Coagulant Concentration (mg/l) | Total Solids Recovery (%) | Protein Recovery (%) |
|---|---|---|
| 5020 | 68 | 92 |
| 4710 | 60 | 80 |
| 2390 | 47 | 69 |

Table 140 Results of dispersed air flotation on tuna wastewater (43)

| Chemical Additive | Parameter | Influent (mg/l) | Reduction % |
|---|---|---|---|
| | | (Average of five runs) | |
| Treto lite<br>7-16 mg/l | BOD | 4400 | 47 |
| | O&G | 273 | 68 |
| | SS | 882 | 30 |
| | | (Average of eight runs) | |
| Drew 410<br>3-14 mg/l | BOD | 211 | 47 |
| | O&G | 54 | 50 |
| | SS | 245 | 30 |

adjusted to insure uninterrupted flow to the flotation cell. This can be very useful in avoiding system shutdowns. A typical dissolved air flotation system is shown in Figure 86, and a typical dissolved air flotation unit is shown in Figure 87.

Air bubbles usually are negatively charged. Suspended particles or colloids may have a significant electrical charge providing either attraction or repulsion with the air bubbles. Flotation aids can be used to prevent air bubble repulsion. In treating industrial wastes with large quantities of emulsified grease or oil, it is usually beneficial to use alum, or lime, and an anionic polyelectrolyte to provide consistently good removal (40).

Emulsified grease or oil normally cannot be removed without chemical coagulation (41). The emulsified chemical coagulant should be provided in sufficient quantity to absorb completely the oil present whether free or emulsified. Good flotation properties are characterized by a tendency for the floc to float with no tendency to settle downward. Excessive coagulant additions result in a heavy floc which is only partially removed by air flotation. With oily wastewaters such as those found in the fish processing industry, minimum emulsification of oils should result if a recycle stream only, rather than the entire influent, were passed through the pressurization tank. This would insure that only the stream (having been previously treated) with the lower oil content would be subjected to the turbulence of the pressurization system. The increased removals achieved, of course, would be at the expense of a larger flotation unit than that which would be needed without recycle.

The water temperature determines the solubility of the air in the water under pressurization. With lower water temperature, a lower quantity of recycle is necessary to dissolve the same quantity of air. The viscosity of the water increases with a decrease in temperature so that flotation units must be made larger to compensate for the slower bubble rise velocity at low temperatures. Mayo (40) recommended that flotation units for industrial application be sized on a flow basis for suspended solids concentrations less than 5000 mg/l. Surface loadings should not exceed 81 l/sq m/min (2 gal./sq ft/min). The air-to-solids ratio is important, as well. Mayo (40) recommended 0.02 kg of air per kg of solids to provide a safe margin for design.

Flotation is in extensive use among food processors for wastewater treatment. Mayo (40) presented data showing high influent BOD and solids concentrations, each in the range of 2000 mg/l. Reductions reached 95 percent BOD removal and 99.7 percent solids removals, although most removals were five percent to 20 percent lower. The higher removals were attainable using appropriate chemical additions and, presumably, skilled operation. A full scale dissolved air flotation unit was recently installed at a tuna plant on Terminal Island, California. Table 141 shows the results of the pilot plant study that preceeded the full scale

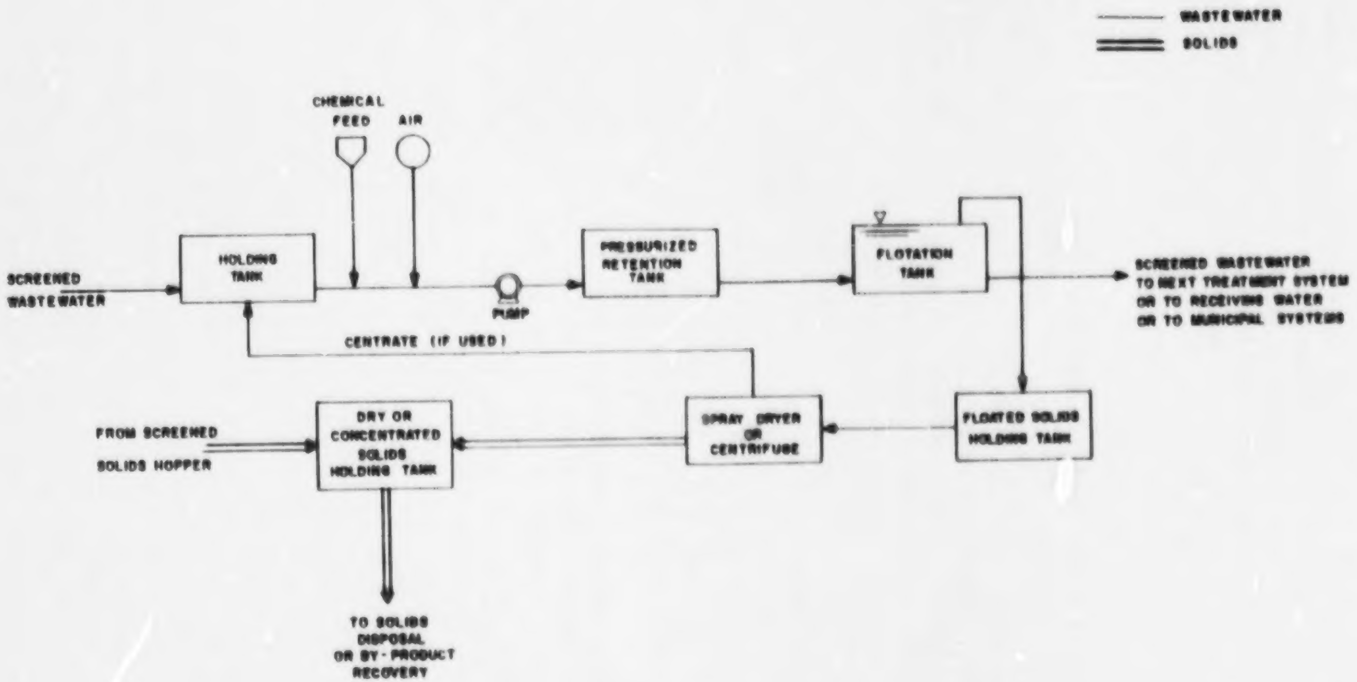

WASTEWATER
SOLIDS
CHEMICAL FEED
AIR
SCREENED WASTEWATER
HOLDING TANK
PUMP
PRESSURIZED RETENTION TANK
FLOTATION TANK
SCREENED WASTEWATER TO NEXT TREATMENT SYSTEM OR TO RECEIVING WATER OR TO MUNICIPAL SYSTEMS
CENTRATE (IF USED)
FROM SCREENED SOLIDS HOPPER
DRY OR CONCENTRATED SOLIDS HOLDING TANK
SPRAY DRYER OR CENTRIFUGE
FLOATED SOLIDS HOLDING TANK
TO SOLIDS DISPOSAL OR BY-PRODUCT RECOVERY

Figure 86. Typical dissolved air flotation system for seafood processing operations.

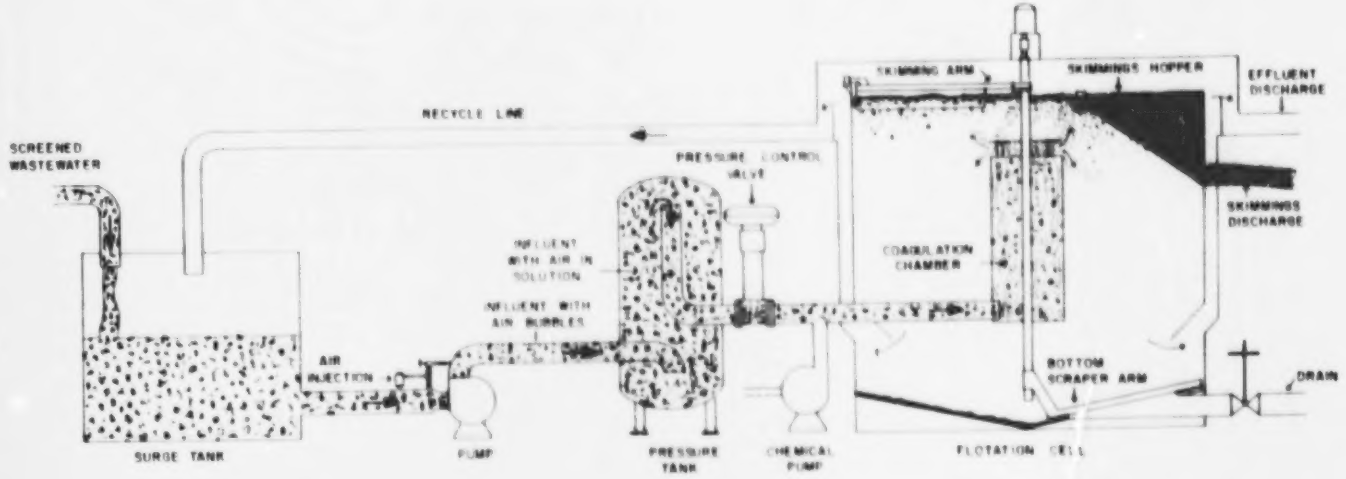

RECYCLE LINE
SCREENED WASTEWATER
SURGE TANK
AIR INJECTION
PUMP
INFLUENT WITH AIR BUBBLES
INFLUENT WITH AIR IN SOLUTION
PRESSURE TANK
PRESSURE CONTROL VALVE
CHEMICAL PUMP
SKIMMING ARM
SKIMMINGS HOPPER
EFFLUENT DISCHARGE
SKIMMINGS DISCHARGE
COAGULATION CHAMBER
BOTTOM SCRAPER ARM
DRAIN
FLOTATION CELL

Figure 87 . Dissolved air flotation unit (Carborundum Company).

unit and Table 142 gives the percent reductions calculated from the samples collected in 1973. Operational difficulties are thought to have reduced the effectiveness of the unit. The pilot plant treated a flow of 0.5 to 1.0 l/sec (7.5 to 15 gpm) with a constant recycle of 0.5 l/sec (7.5 gpm). The full scale plant treated a flow of 28 l/sec (450 gpm) with no recycle.

Two more full scale dissolved air flotation units for tuna plants have been ordered and are due to start in 1974 according to Robbins of Envirotech Corporation (35).

At least two significant pilot plant studies have been performed on shrimp wastewater, one in Louisiana and the other in Alaska. Table 143 and Table 144 list the results of the respective studies.

The Louisiana shrimp study was conducted by Region VI E.P.A. and Dominique, Szabo, and Associates, Inc. using a Carborundum Company dissolved air flotation pilot unit which treated a 3.1 l/sec (50 gpm) flow using 1:1 recycle, and 170 l/hr (6 cu ft/hr) air at a pressure of 2.7 atm (40 psig).

The Alaska shrimp study was conducted by the National Marine Fisheries Service Technology center, using a Carborundum Company dissolved air flotation pilot unit, which treated a 3.1 l/sec (50 gpm) flow using 10 percent recycle.

Preliminary indicators from the Louisiana shrimp show that alum at 75 ppm and a polyelectrolyte at 0.5 - 5.0 ppm produce the best removal efficiencies (see Figure 88).

Various chemical additives and concentrators were tested in Alaska with inconclusive results. All flocculants worked better than no additives but none were significantly better than alum alone at around 200 mg/l. Sea water apppeared to reduce the effectiveness of the polyelectrolyte used during the test.

During the summer of 1972 a study was conducted by the National Marine Fisheries Service to investigate means of reducing waste discharge problems as a result of fish meal and oil production. Bailwater used to unload menhaden was treated using a pilot scale dissolved air flotation unit. This treatment allowed increased recirculation of bailwater, decreasing the soluble plant load. The removal efficiencies are listed in Table 145. The plant treated 4.1 l/sec (65 gpm) with 50 percent recycle and 50 psig. The results showed that dissolved air flotation units can extend bailwater re-use, but that sludge disposal must be resolved.

A full scale dissolved air flotation unit has also been installed in the sardine industry, however, mechanical problems have hindered operation thus far. Results are shown in Table 146.

Table 141 Efficiency of EIMCO flotator pilot plant on tuna wastewater (43)

| Chemical Additive | Parameter | Influent (mg/l) | Reduction % |
|---|---|---|---|
| | | (Based on one run) | |
| Lime (pH 10.0 - 10.5)<br>Polymers: | BOD-5 | 3533 | 65 |
| Cationic, 0.05 mg/l | O&G | 558 | 66 |
| Anionic, 0.10 mg/l | SS | 1086 | 66 |
| Lime, 400 mg/l | BOD-5 | | 22 |
| Ferric chloride, 45 mg/l | O&G | | 81 |
| | SS | | 77 |

Table 142 Efficiency of EIMCO flotator full scale plant on tuna wastewater (44)

| Chemical Additive | Parameter | Influent (mg/l) | Reduction % |
|---|---|---|---|
| | | (Based on two runs) | |
| Sodium Aluminate 120 mg/l | COD | 2850 | 37 |
| Polymer | SS | 1170 | 56 |
| | | (Based on one run) | |
| Alum | COD | 5100 | 58 |
| Polymer | SS | 667 | 65 |

The Canadians have constructed a demonstration wastewater treatment plant capable of handling the estimated flow of 47 l/sec (750 gpm) from a salmon and ground fish filleting plant. It was later modified to treat herring bailwater and roe recovery operations as well. Results of the study by The Fisheries Research Board of Canada on this operation are shown in Table 147.

The previous air flotation case studies have shown various removal efficiencies depending on species, chemical additives and effluent concentrations. One reason for the various removal efficiencies reported appears to be due to the efficiency being a function of influent concentration. Figure 89 plots the percent removal versus COD concentration using the results of the sardine, menhaden, Gulf shrimp and tuna air flotation studies. The removals are probably a function of the species being processed; however, there appears to be a strong tendency for the efficiency to increase as the concentration increases. The tuna and shrimp concentrations and removal efficiencies were lower than the sardine and menhaden concentrations and removal efficiencies. This relation also holds for the sardine wastewater where the efficiency appears to increase about 25 percent as the COD concentration increases by a factor of four, from 5000 to 20,000 mg/l.

The case studies documented in this report indicate that air flotation systems can provide good removal of pollution loads from seafood processing wastewater, however, the results are highly dependent on operating procedure. In most cases, optimum removal efficiencies are yet to be established, but it is expected that the technology should become standardized over the next few years as an increasing number of units are tested. It also appears that the COD removal efficiency is a function of concentration, increasing as the influent concentrations increase.

The air flotation technology can also be operated at lower efficiencies to serve as "primary" treatment in advance of a physical-chemical or biological polishing step, if that mode proves advantageous from the standpoint of cost-effectiveness.

Appendices A and B contain selected bibliographies of air flotation use within the seafood industry and meat and poultry industry, respectively.

## Biological treatment

Biological treatment is not practiced in U.S. seafood industries except for a small pilot project in Maryland at a blue crab processing plant and full-scale systems at two shrimp plants in Florida. Sufficient nutrients are available in most seafood wastewaters, however, to indicate that such wastewaters are amenable to aerobic biological treatment.

Table 143 Efficiency of Carborundum pilot plant on Gulf shrimp wastewater (45)

| Cnemical Additive | Parameter | Influent (mg/l) | Reduction % |
|---|---|---|---|
| | | (Average of five runs, one each with 5, 4, 2, 1, and 0.5 mg/l polymer) | |
| Acid (to pH 5) | BOD-5 | 1428 | 70 |
| Alum 75 mg/l | COD | 3400 | 64 |
| Polymer | SS | 559 | 83 |
| | | (Average of two runs, one each at 75 gpm and 25 gpm with 2 mg/l polymer) | |
| Acid (to pH 5) | COD | 3400 | 51 |
| Alum 75 mg/l | SS | 440 | 68 |
| Polymer | O&G | 852 | 85 |

Table 144 Efficiency of Carborundum pilot plant on Alaska shrimp wastewater

| Chemical Additive | Parameter | Reduction % |
|---|---|---|
| | (Average of twenty-two runs) | |
| Alum 200 mg/l | COD | 73 |
| Polymer | SS | 77 |

Table 145 Efficiency of Carborundum pilot plant on menhaden bailwater (46)

| Chemical Additive | Parameter | Influent (mg/l) | Reduction % |
|---|---|---|---|
| | (Average of five runs) | | |
| Alum or | COD | 94,200 | 80 |
| Acid pH 5-5.3 | SS | -- | 87 |
| Polymer | O&G | -- | near 100 |

Note: SS and O&G determined by volume change.

Table 146 Efficiency of full scale dissolved air flotation on sardine wastewater (22)

| Chemical Additive | Parameter | Reduction % |
|---|---|---|
| | (Average of seven runs) | |
| Alum | COD | 74 |
| Polymer | O&G | 92 |
| | SS | 87 |

Table 147 Efficiency of full scale dissolved air flotation on Canadian seafood wastewater (34)

| Chemical Additive | Species | Removal Percentage | | |
|---|---|---|---|---|
| | | COD | Oil | SS |
| Alum Polymer | Salmon | 84 | 90 | 92 |
| | Herring | 72 | 85 | 74 |
| | Groundfish | 77 | -- | 86 |
| | Stickwater | -- | 95 | 95 |

Comments: Sludge represents about three percent of flow.

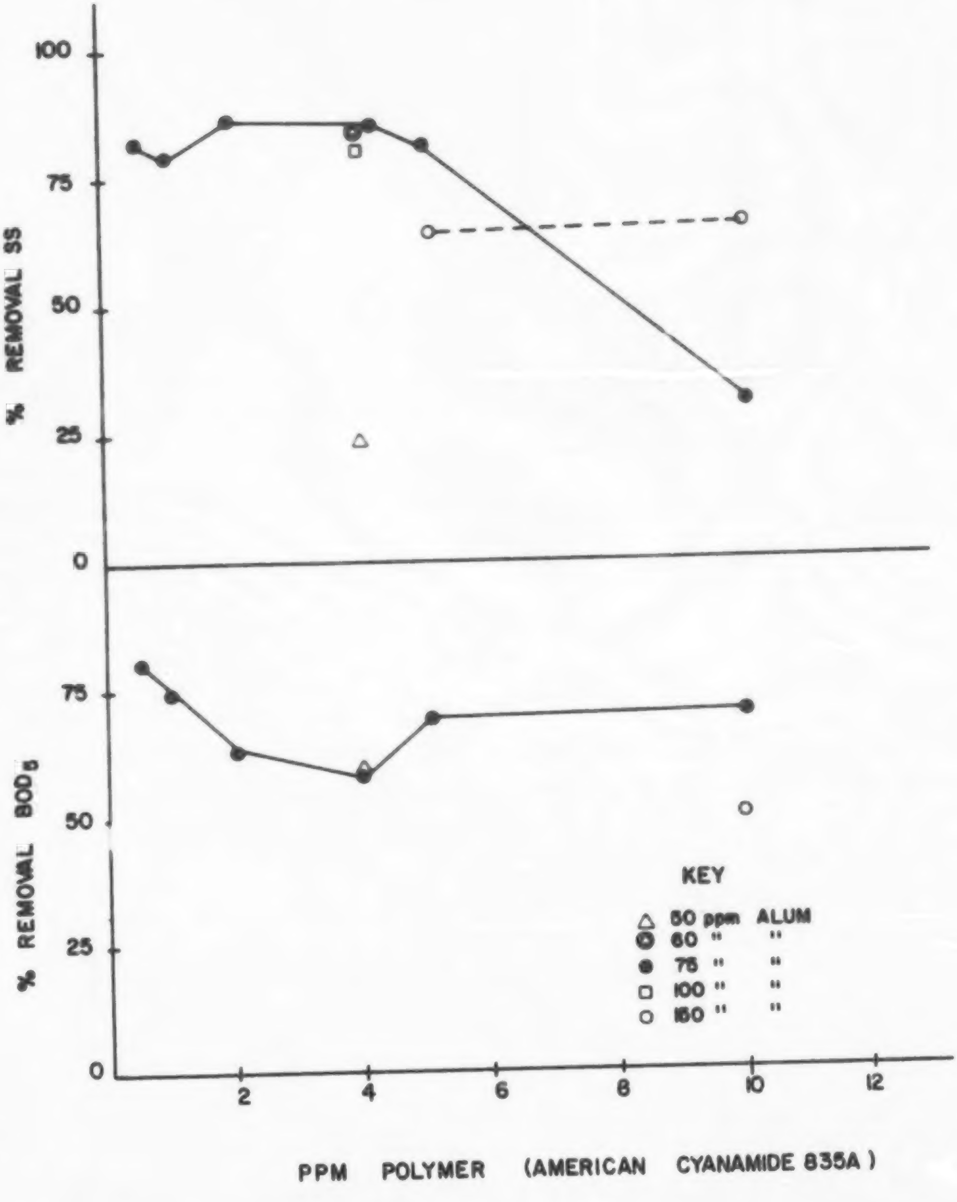


Figure 88. Removal efficiency of DAF unit used in Louisiana shrimp study - 1973 results (Dominique, Szabo Associates, Inc.).

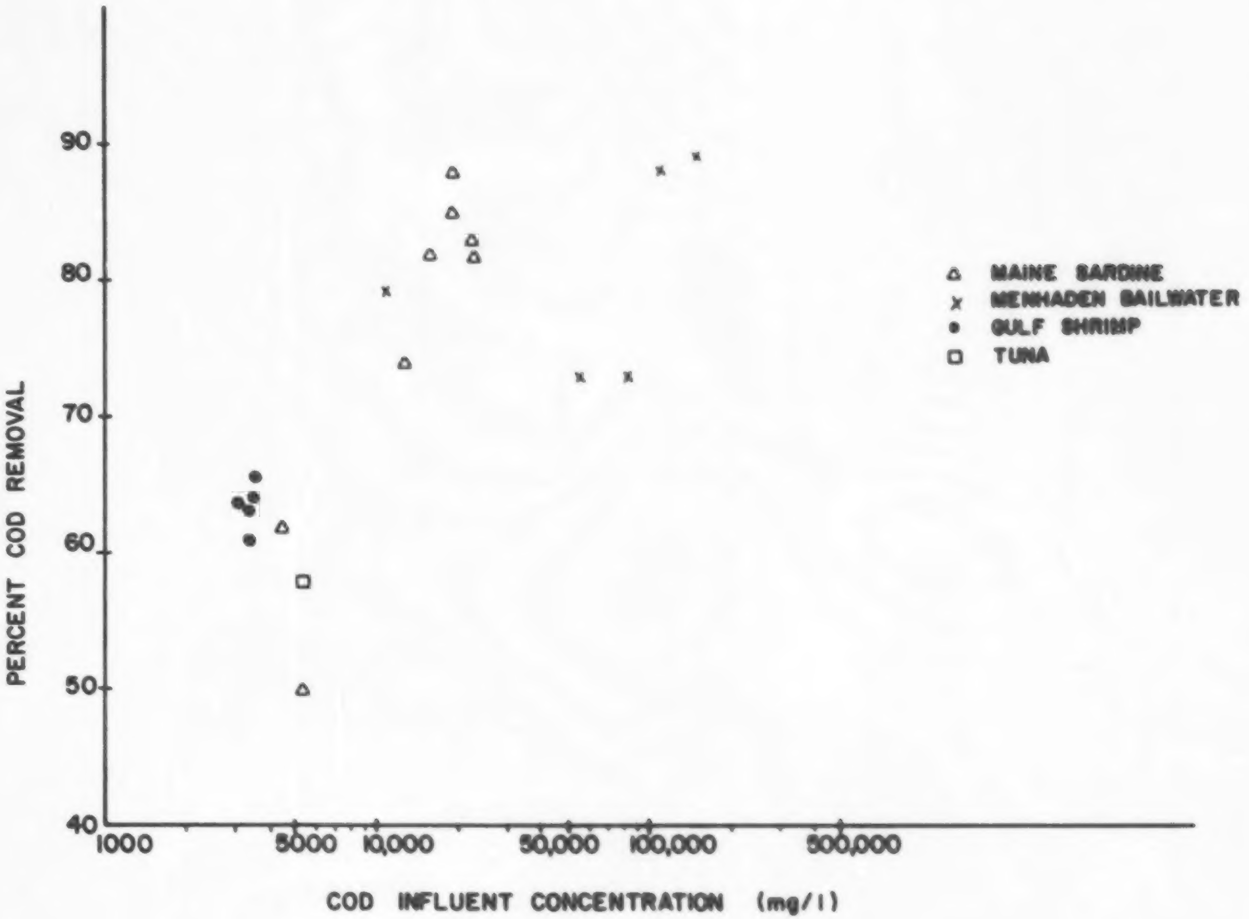


Figure 89. Air flotation efficiency versus influent COD concentration for various seafood wastewaters.

Primary stage removal of solids and oil and greases should precede biological treatment. Without this pretreatment, several problems can develop: 1) oil and grease can interfere with oxygen transfer in an activated sludge system; and 2) solids can clog trickling filters.

The salt found in nearly all wastewaters discourages the consideration of anaerobic processes. Salt is toxic to anaerobic bacteria, and although a certain tolerance to higher salt levels can be developed in carefully controlled (constant input) systems, fluctuating loads continue to be inhibitory or toxic to these relatively unstable systems. Aerobic biological systems, although inhibited by "shock loadings" of salt, have been demonstrated at full scale for the treatment of saline wastes of reasonably constant chloride levels. The effectiveness of any form of biological oxidation, however, is subject to the variations of the raw waste loads and salinity encountered in many segments of the fish processing industry.

## Activated Sludge

The activated sludge process consists of suspending a concentrated microbial mass in the wastewater in the presence of oxygen. Carbonaceous matter is oxidized mainly to carbon dioxide and water. Nitrogenous matter is concurrently oxidized to nitrate. The conventional activated sludge process is capable of high levels of treatment when properly designed and skillfully operated. Flow equilization by means of an aerated tank can minimize shock loadings and flow variations, which are highly detrimental to treatment efficiency. The process produces a sludge which is composed largely of microbial cells, as described above. Oily materials can have an adverse effect. A recent study concluded the influent (petroleum-based) oil levels should be limited to 0.10 kg/day/kg MLSS (0.10 lb/day/lb MLSS).

The nature of the waste stream, the complexity of the system and the difficulties associated with dewatering waste activated sludge indicate that for most applications the activated sludge system of choice would be the extended aeration modification.

A typical extended aeration system which could be used for a seafood processing operation is shown in Figure 90 and is similar to conventional activated sludge, except that the mixture of activated sludge and raw materials is maintained in the aeration chamber for longer periods of time. The common detention time in extended aeration is one to three days, in contrast to the conventional six hours. This prolonged contact between the sludge and raw waste provides ample time for the organic matter to be assimilated by the sludge and also for the organisms to metabolize the organics. This allows for substantial removals of organic matter. In addition, the organisms undergo considerable endogenous respiration, which oxidizes much of the cellular

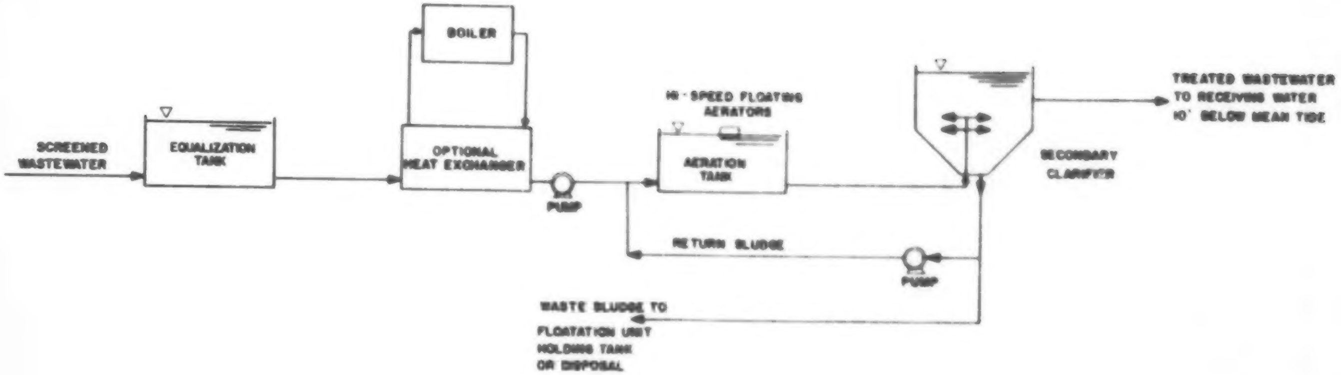

SCREENED WASTEWATER
EQUALIZATION TANK
BOILER
OPTIONAL HEAT EXCHANGER
PUMP
HI-SPEED FLOATING AERATORS
AERATION TANK
RETURN SLUDGE
PUMP
SECONDARY CLARIFIER
TREATED WASTEWATER TO RECEIVING WATER 10' BELOW MEAN TIDE
WASTE SLUDGE TO FLOATATION UNIT HOLDING TANK OR DISPOSAL

Figure 90. **Typical extended aeration system for seafood processing operations.**

biomass. As a result, less sludge is produced and little is discharged from the system as waste activated sludge.

In extended aeration, as in the conventional activated sludge process, it is necessary to have a final sedimentation tank.

The solids resulting from extended aeration are finely dispersed and settle slowly, requiring a long period of settling. The system is relatively resistant to shock loadings, provided the clarifier has sufficient surface area to prevent the loss of biomass during flow surges. Extended aeration, like other activated sludge systems, requires a continuous flow of wastewater to nurture the microbial mass. The re-establishment of an active biomass in the aeration tank requires several days to a few weeks if the unit is shut down or the processing plant ceases to operate for significant periods of time.

Riddle (26) studied the efficiency of biological systems on smelt and perch wastewater. He found a 90 percent removal of unfiltered BOD-5 after 10 days aeration, and 90 percent removal of filtered BOD-5 after two days aeration in a batch reactor (see Figures 91 and 92). Tests in a continuous reactor showed that maximum BOD-5 removal (80 percent soluble and 45 percent unfiltered) could be achieved with a 7.5 hour detention time, sludge recycle and a three day sludge age or a five day detention time with no sludge recycle.

Robbins (35) reports that an activated sludge plant in Japan has been especially designed for fish wastes. The wastewater flow is approximately 0.27 mgd and the 5 day BOD concentration ranges from 1000 to 1900 mg/l. The results of pilot plant studies conducted using a 10 hour separation time and the organic and hydraulic loadings listed are shown in Table 148. Bulking occurred when the organic loading rate exceeded 0.31 lb/cu ft/day.

Although treatment units are available in all size ranges, it is unlikely activated sludge will prove to be the most cost-effective treatment where processing is intermittent, or plant flows are so large that alternative systems of suitable scale are available. The wide variation in quality of the small package extended aeration systems now available dictates careful selection of the equipment, if the process is to approach the removals now achieved by well-operated municipal installations.

Table 149 shows the effectiveness of a package unit on wastewater from a plant processing Atlantic oysters and blue crab. The flow from this plant was quite low, averaging only 0.09 l/sec (2000 gpd).

## Rotating Biological Contactor

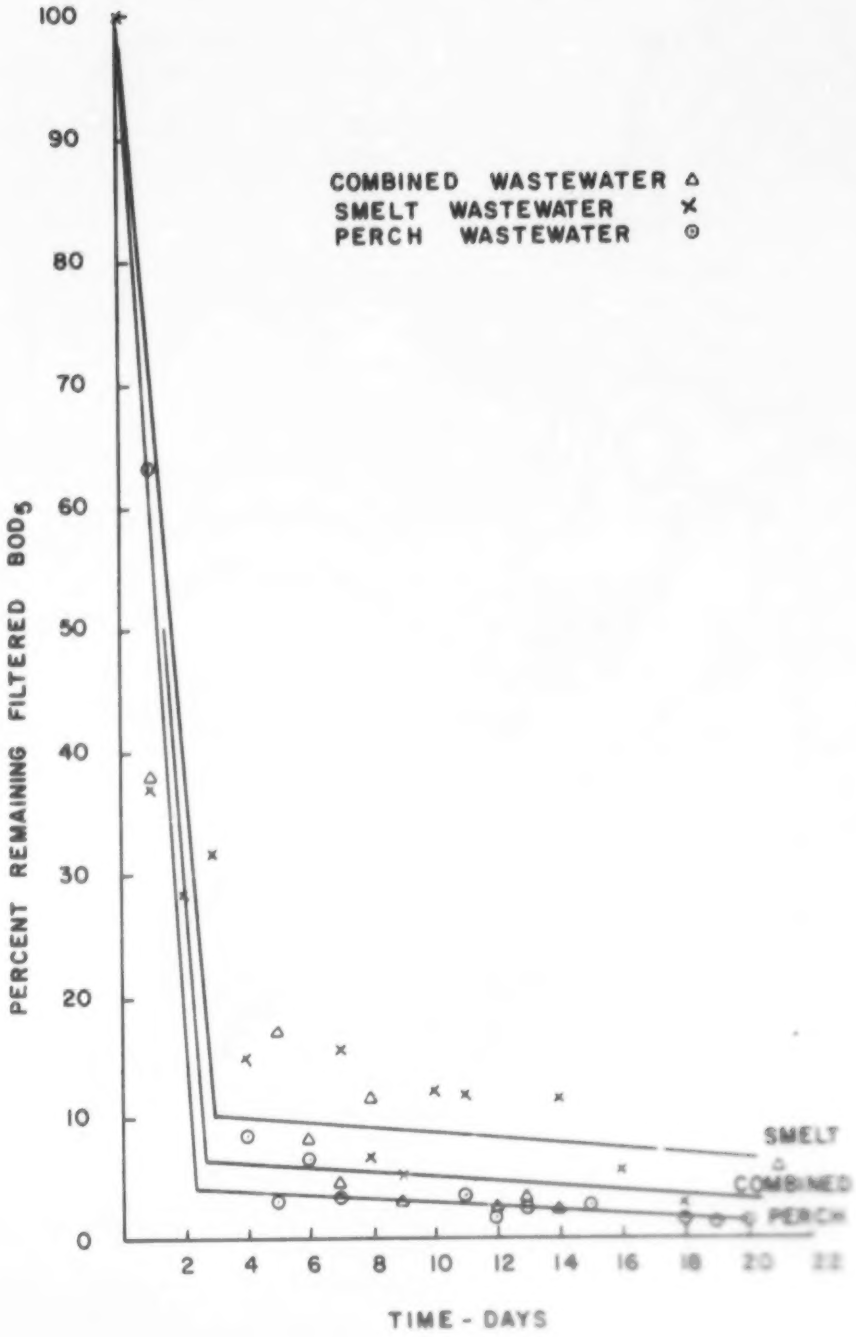


Figure 91. Removal rate of filtered BOD in a batch aeration reactor.

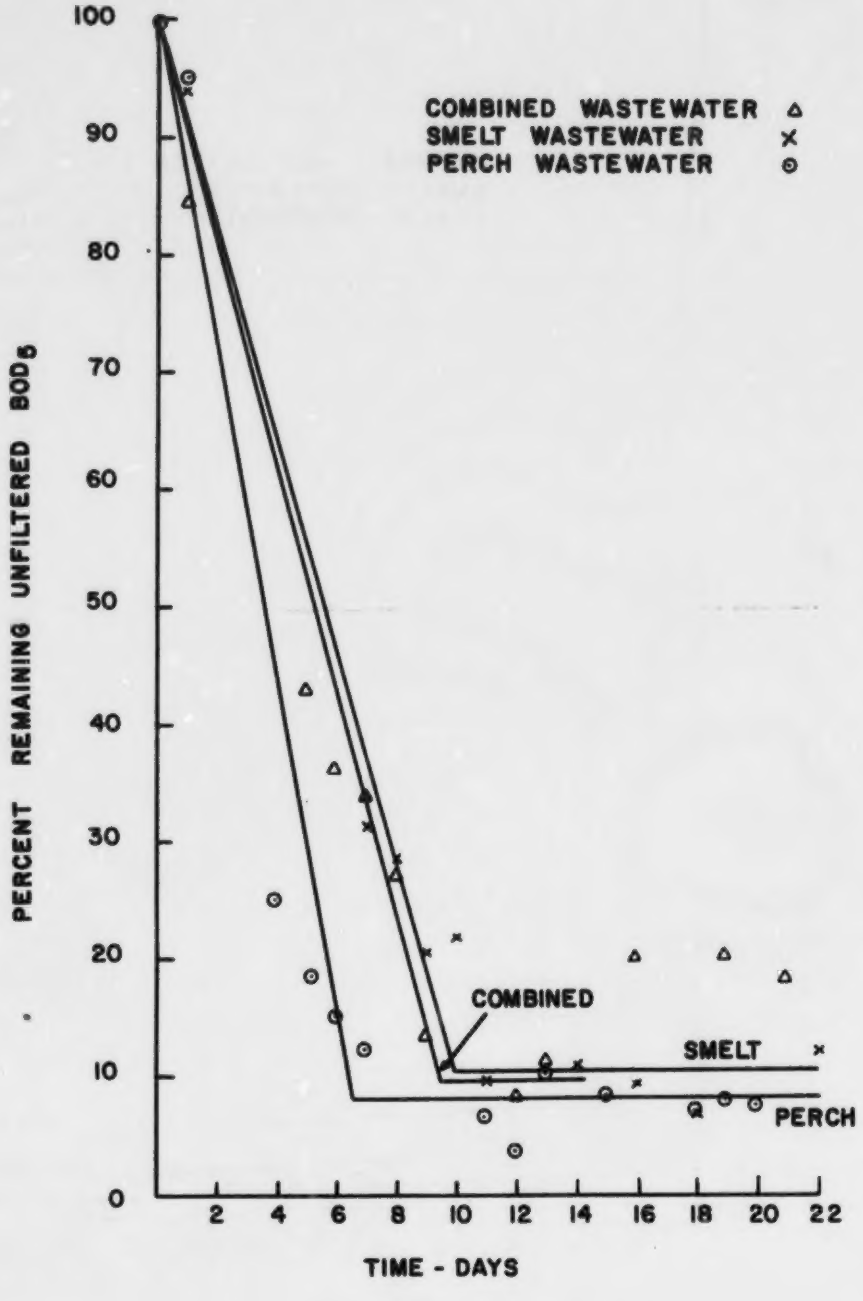


Figure 92. Removal rate of unfiltered BOD in a batch aeration reactor.

Table 148 Activated sludge pilot plant results (35)

| Parameter | Raw Waste | BOD Loading (lb/cu ft/day) | | | |
|---|---|---|---|---|---|
| | | 0.075 | 0.14 | 0.21 | 0.26 |
| BOD-5 (mg/l) | 1000 | 5 | 10 | 13 | 27 |
| % Removal | -- | 99.5 | 99.0 | 98.7 | 97.3 |

Table 149 Efficiency of Chromaglas package plant on blue crab and oyster wastewater

| Parameter | Influent | Percentage Reduction |
|---|---|---|
| BOD | 400-1200 mg/l | 80 - 90% |
| Suspended Solids | -- | Effluent level = 160 mg/l |

The Rotating Biological Contactor (RBC), or Biodisc unit, consists of light-weight discs approximately 1.3 cm (0.5 in.) thick and spaced at 2.5 to 3.8 cm (1 to 1.5 in.) on centers. The cylindrical discs, which are up to 3.4 m (11 ft) in diameter, are mounted on a horizontal shaft and placed on a semicircular tank through which the wastewater flows. Clearance between the discs and the tank wall is 1.3 to 1.9 cm (0.5 to 0.75 in.). The discs rotate slowly, in the range of five to 10 rpm, passing the disc surface through the incoming wastewater. Liquid depth in the tank is kept below the center shaft of the discs. Reaeration is limited by the solubility of air in the wastewater and rate of shaft rotation.

Shortly after start-up, organisms begin to grow in attached colonies on the disc surfaces, and a typical growth layer is usually established within a week. Oxygen is supplied to the organisms during the period when the disc is rotating through the atmosphere above the flowing waste stream. Dense biological growth on the discs provides a high level of active organisms resistant to shock loads. Periodic sloughing produces a floc which settles rapidly; and the shear-forces developed by rotation prevents disc media clogging and keeps solids in suspension until they are transferred out of the disc tank and into the final clarifier. Normally, sludge recycling shows no significant effect on treatment efficiency because the suspended solids in the mixed liquor represent a small fraction of the total culture when compared to the attached growth on the disc.

Removal efficiency can be increased by providing several stages of discs in series. European experience on multi-stage disc systems indicates that a four stage disc plant can be loaded at a 30 percent higher rate than a two stage plant for the same degree of treatment. Because the BOD removal kinetics approach a first order reaction, the first stage should not be loaded higher than 120 g BOD/day/sq m disc surface. If removal efficiencies greater than 90 percent are required, three or four stages should be installed. Mixtures of domestic and food processing wastes in high BOD concentrations can be treated efficiently by the RBC-type system.

Because 95 percent of the solids are attached to the discs, the RBC unit is less sensitive to shock loads than activated sludge units, and is not upset by variations in hydraulic loading. During low flow periods the RBC unit yields effluents of higher quality than at design flow. During periods of no flow, effluents can be recycled for a limited time to maintain biological activity.

Both the Rotating Biological Contactor and the trickling filter systems utilize an attached culture. However, with the rotating disc the biomass is passed through the wastewater rather than wastewater over the biomass, resulting in less clogging for the RBC unit. Continuous wetting of the entire biomass surface also prevents fly growth, often associated with conventional trickling filter operations.

The RBC system requires housing to protect the biomass from exposure during freezing weather and from damage due to heavy winds and precipitation.

A pilot RBC system has been studied in Canada on salmon canning wastewater, which had previously been treated by an air flotation system (32). The pilot plant was obtained from Autotrol Corporation and was rated at about 0.44 l/sec (7 gpm). The pilot system consists of a wet well, a three stage treatment system and a secondary clarifier with a rotating sludge scoop. In general, the unit performed quite well, with reductions of over 50 percent in COD being obtained two days after start-up. The discs reached a steady state condition in one week. The unit operated satisfactorily at loadings up to 20 lbs COD/1000 sq ft/day, showing good stability in the face of fluctuating loads. Under light solids loading algal growth developed in the clarifier and the last disc section. Consequently, all effluent samples were filtered prior to COD analysis. Under moderate flow conditions the clarifier functioned well, but occasionally the suspended solids level rose about 50 mg/l, indicating some problems in this area. This carry-over became very pronounced under heavy solids loading. About 80 percent removal of applied COD was obtained for loadings of up to 20 lbs COD/1000 sq ft/day. Removal of COD at each stage is highly variable, and does not appear to be a function of the applied load. In general, up to one-half of the COD removal was achieved in the first section, up to 20 percent was removed in the second stage, and up to 15 percent removed in the third stage.

### High-Rate Trickling Filter (HRTF)

A trickling filter consists on a vented structure of rock, fiberglas, plastic, or redwood media on which a microbial flora develops. As wastewater flows downward over the structure, the microbial flora assimilates and metabolizes the organic matter. The biomass continuously sloughs and is readily separated from the liquid stream by sedimentation. The resulting sludge requires further treatment and disposal as described previously.

The use of artificial media promotes air circulation and reduces clogging, in contrast to rock media. As a result, artificial media beds can be over twice as deep as rock media beds, with correspondingly longer contact times. Longer contact times and recirculation of the liquid flow enhance treatment efficiency. The recirculation of settled sludge with the liquid stream is also claimed to improve treatment.

The system is simple in operation, the only operational variable being recycle rate. The treatment efficiency of a well-designed deep-bed trickling filter tower of 14 ft or more with high recycle can be superior to that of a carelessly operated activated sludge system. The system is not particularly sensitive to shock loadings but is severely impaired by wastewater temperatures below 73°C (45°F). Below 2°C (35°F), treatment efficiency is minimal. The effect of grease and oil in trickling filter influent has not been evaluated. They would likely be detrimental.

## Ponds and Lagoons

The land requirements for ponds and lagoons limit the locations at which these facilities are practicable. Where conditions permit, they can provide reasonable treatment alternatives.

Lagoons are ponds in which wastewater is treated biologically. Naturally aerated lagoons are termed oxidation ponds. Such ponds are 0.9 to 1.2 m (3 to 4 ft) deep, with oxidation taking place chiefly in the upper 0.45 m (18 in.). Mechanically aerated lagoons are mixed ponds over 1.8 m (6 ft) and up to 6.1 m (20 ft) deep, with oxygen supplied by a floating aerator or compressed air diffuser system. The design of lagoons requires particular attention to local insulation, temperatures, wind velocities, etc. for critical periods. These variables affect the selection of design parameters. Loading rates vary from 22 to 112 kg BOD/day/ha (20 lb to 100 lb/day/acre), and detention times from three to 50 days. A typical aerated lagoon system which could be used for a seafood processing operation is shown in Figure 93.

Although not frequently used in the fish processing industry, lagoons are in common use in other food processing industries. Serious upsets can occur. The oxidation pond may produce too much algae, the aerated lagoon may turn septic in zones of minimal mixing, etc.; and recovery from such upsets may take weeks. The major disadvantage of lagoons is the large land requirement. In regions where land is available and soil conditions make excavation feasible, the aerobic lagoon should find application in treating fish wastes. Where the plant discharges no salt water, anaerobic and anaerobic-aerobic types of ponds may also be utilized. Aerated lagoons are reported to produce an effluent suspended solids concentration of 260 to 300 mg/l, mostly algae, while anaerobic ponds produce an effluent with 80 to 160 mg/l suspended solids (37). A combined activated sludge lagoon system in Florida is reported to remove 97 percent of the BOD and 94 percent of the suspended solids from shrimp processing wastewater.

## Land disposal

"Zero-discharge" technology is practicable where land is available upon which the processing wastewaters may be applied without jeopardizing groundwater quality. The site, surrounded by a retaining dike, should sustain a cover crop of grass or

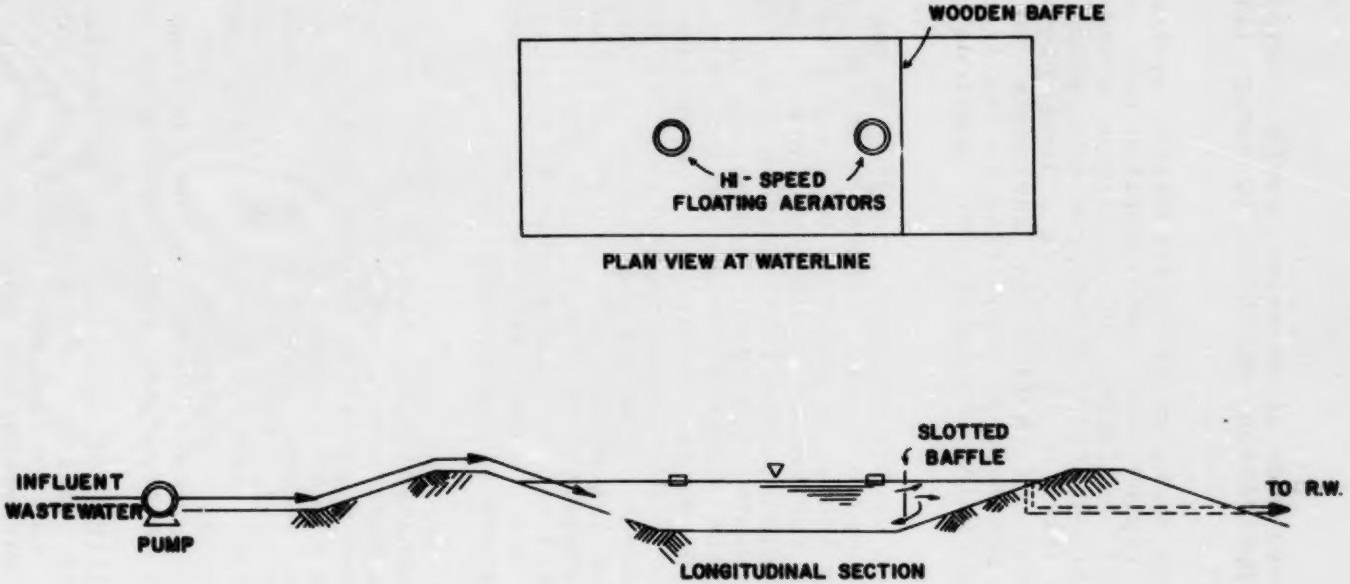

WOODEN BAFFLE
HI - SPEED
FLOATING AERATORS
PLAN VIEW AT WATERLINE
SLOTTED
BAFFLE
INFLUENT
WASTEWATER
PUMP
TO R.W.
LONGITUDINAL SECTION

Figure 93. Typical aerated lagoon system.

other vegetation. Where such sites exist, serious consideration can be given to land application, particularly spray irrigation, of treated wastewaters.

Wastes are discharged in spray or flood irrigation systems by: 1) distribution through piping and spray nozzles over relatively flat terrain or terraced hillsides of moderate slope; or 2) pumping and disposal through ridge-and-furrow irrigation systems, which allow a certain level of flooding on a given plot of land. Pretreatment for removal of solids is advisable to prevent plugging of the spray nozzles, or deposition in the furrows of a ridge-and-furrow system, which may cause odor problems or clog the soil.

In a flood irrigation system the waste loading in the effluent would be limited by the waste loading tolerance of the particular crop being grown on the land. It may also be limited by the soil conditions or potential for vector or odor problems. Wastewater distributed in either manner percolates through the soil and the organic matter in the waste undergoes biological degradation. The liquid in the waste stream is either stored in the soil or discharged into the groundwater. A variable percentage of the waste flow can be lost by evapotranspiration, the loss due to evaporation to the atmosphere through the leaves of plants. The following factors affect the ability of a particular land area to absorb wastewater: 1) character of the soil; 2) stratification of the soil profile; 3) depth to groundwater; 4) initial moisture content; 5) terrain and groundcover; 6) precipitation; 7) temperature; and 8) wastewater characteristics.

The greatest concern in the use of irrigation as a disposal system is the total dissolved solids content and especially the sodium content of the wastewater. Salt water waste flows would be incompatible with land application technology at most sites. Limiting values which may be exceeded for short periods but not over an entire growing season were estimated, conservatively (47), to be 450 to 1000 mg/l. Where land application is feasible it must be recognized that soils vary widely in their percolation properties. Experimental irrigation of a test plot is recommended in untried areas. Cold climate systems may be subjected to additional constraints, including storage needs.

The long-term reliability of spray or flood irrigation systems depends on the sustained ability of the soil to accept the wastewater. Problems in maintenance include: 1) controlling salinity levels in the wastewater; 2) compensating for climatic limitations; and 3) sustaining pumping without failure. Many soils are improved by spray irrigation.

## Multi-Process Treatment Design Consideration

Waste characterization studies reveal the general ranges and concentrations of each specific processing subcategory; however, for design purposes it may often be necessary to know the nature of the combined waste stream from several commodities being processed simultaneously. Short term on-site waste and wastewater investigations are suggested so that any synergistic and/or antagonistic interactors can be determined. A combined waste stream could conceivably be more amenable to treatment than a single source because of possible smoothing of peak hydraulic and/or organic loading, neutralization of pH or dilution of saline conditions.

Each stream may individually dictate the design considerations. For instance, the fibrous nature of salmon canning waste will likely dictate the screening method used or a waste stream with high flow will likely dictate hydraulic loading of the system.

Another design problem is caused by sequential seasonal processing of different commodities. This condition is also prevaleht in the seafood industry. Optimum waste treatment design conditions for one effluent will normally not be identical to those for the next. As an example, the sequential processing of shrimp and oysters would cause problems. Even though their effluent concentrations are similar, the wastewater flow volume is approximately eight times higher in the typical shrimp processing plant. Problems such as this will necessitate adaptations to normal design procedures or perhaps even demand the use of more than one treatment train.

During on-site waste management studies consideration should also be given to segregation of certain unit process streams. Significant benefits may be realized by using this technique. For example, treatment of a high concentrated waste flow can be more efficient and economical. In addition, by-product development normally centers on the segregation and concentration of waste producing processes. Uncontaminated cooling water should remain isolated from the main wastewater effluent. This water could either be reused or discharged directly.

## Treatment Design Assumptions

Tables 150 and 153 summarize the treatment efficiencies assumed for the recommended technologies. The screen removal efficiencies and dry-weight to wet-weight percentages listed in Table 150 were calculated from the screened solids samples collected during this study. These samples were collected using a 20-mesh Tyler screen and analyzed as discussed in Sections V and VI. Table 151 lists the removal efficiencies assumed for the air flotation, aerated lagoon and extended aeration technologies. It is noticed that the air flotation removal efficiency is assumed to vary with the grease and oil content of the wastewater. Also, there are lower concentration limits which cannot be exceeded either due to the inherent operation of the system (aerated lagoon or extended aeration), or because of minimum detection thresholds (grease and oil cannot be adequately recovered below 5 mg/l). Table 152 lists the estimated in-plant waste water flow reductions and the associated pollutional loadings reductions for the 1983 effluent limitations and new source performance standards.

## Establishing Effluent Limitations

Because there are few existing waste water treatment facilities at the plant level, the 30-day and the daily maximum limitations are based on engineering judgment and the consideration of the operating characteristics of similar treatment systems within the meat processing industry, municipal waste treatment systems, or other segments of the seafood as well as the food processing industry.

The daily maximum and the maximum 30-day average limitations are based on the formulas presented in Figure 94. In the case where the engineering design effluent concentration exceeds the thirty day average based on the above calculations, the design concentration is utilized as the basis for the effluent limitation. The corresponding daily maximum limitation is determined by the treatment technology operating characteristic: For aerated lagoon systems the daily maximum is 2 times the thirty day limitation; and for extended aeration systems, 3 times the thirty day limitations.

### Table 150 Removal efficiencies of screens for various seafood wastewater effluents.*

| Subcategory | Typical % Removal Total Suspended Solids | % Solids dry wt./wet wt. |
|---|---|---|
| Finfish | | |
| Alaska salmon canning | 56 | 15 |
| Northwest salmon canning | 56 | 15 |
| Alaska fresh/frozen salmon | 45 | 15 |
| West Coast fresh/frozen salmon | 45 | 15 |
| Alaska bottom fish (halibut) | 75 | 14 |
| Non-Alaska conventional bottom fish | 68 | 18 |
| Non-Alaska mechanized bottom fish | 50 | 21 |
| Sardine canning | 4 | 22 |
| Herring filleting | 25 | 18 |
| Shellfish | | |
| Mechanized clams | 44 | 40 |
| Conventional clams | 24 | 37 |
| Steamed or canned oysters | 56 | 19 |
| Conventional Oysters (Pacific | 32 | - |
| Conventional Oysters (Atlantic) | 44 | - |
| Alaska scallops | 88 | 15 |
| Abalone | 25 | 13 |

*Calculated from sample data contained in this report:

$$\% \text{ removal} = 100\% \frac{TSS}{SS + TSS}$$

Table 151 Removal efficiencies of treatment alternatives.

| Treatment | % Removal or mg/l remaining | | |
|---|---|---|---|
| | BOD | TSS | O & G |
| Air flotation | | | |
| a) Oily species without chemical optimization | 40 | 70 | 85 or 5 mg/l |
| b) Oily species with chemical optimization | 75 | 90 | 90 or 5 mg/l |
| c) Non-oily species without chemical opitmization | 30 | 70 | 85 or 5 mg/l |
| d) Non-oily species with chemical optimization | 50 | 90 | 90 or 5 mg/l |
| Aerated lagoon | 80 or 80 mg/l | 70 or 200 mg/l | 90 or 5 mg/l |
| Extended aeration | 85 or 60 mg/l | 75 or 60 mg/l | 90 or 5 mg/l |
| Grease trap | | | 70 of free oil |

NOTE: Oily species -- menhaden, anchovy, sardine, mackerel, salmon (canned), bottom fish (mechanized), herring, oysters (canned or steamed).

Non-oily species -- bottom fish (conventional), salmon (fresh/frozen), clams, oysters (hand shucked), abalone, urchin, scallops, lobster.

## Table 152

### Estimated practicable in-plant wastewater flow reductions and associated pollutional loadings reductions

| Segment | Wastewater Flow Reduction, % of Total | BOD Reduction % of Total |
|---|---|---|
| Fish meal w/solubles | housekeeping* | 5 |
| Fish meal w/o solubles | -- | 95 |
| Mechanized Salmon | 22 | 4 |
| Hand-butchered Salmon | 10 | 10 |
| Alaskan bottom fish | 43 | 40 |
| Conventional bottom fish | 30 | 23 |
| Mechanized bottom fish | 20 | 20 |
| Sardine | 40 | 20 |
| Herring Filleting | 35 | 27 |
| Conventional Clams | 7 | 7 |
| Mechanized Clams | 12 | 5 |
| Hand-shucked oysters | housekeeping* | 5 |
| Mechanized oysters | 14 | 30 |
| Scallops | housekeeping* | 5 |
| Abalone | housekeeping* | 5 |

* Estimated 5 to 15 percent flow reduction due to good housekeeping practices.

$$\textit{Daily Max} = e^{\ln \mu_s + Z \ln \sigma_s + \ln R}$$

$$\textit{Max 30-day Ave} = e^{\ln \mu_s + \frac{1}{\sqrt{n}} Z \ln \sigma_s + \ln R}$$

Where $\ln \mu_s$ and $\ln \sigma_s$ are the log-normal subcategory mean and standard deviation, respectively; R is the percent of the pollutant parameter remaining after treatment; Z is a constant set equal to 2.33 corresponding to the upper 99 percent confidence interval; and $\eta$ is an assumed sampling frequency of 9 samples per month.

Figure 94. Daily maximum and maximum 30-day average formulas based on log-normal summary data.

# SECTION VIII

## COST, ENERGY, AND NON-WATER QUALITY ASPECTS SUMMARY

The wastewaters from seafood processing plants are, in general, considered to be amenable to treatment using standard physical-chemical and biological systems. Wastewater management in the form of increasing by-product recovery, in-plant control and recycling is not practiced uniformly throughout the industry. Of all the types of seafood processing monitored during this study, the most exemplary from this viewpoint was the menhaden reduction industry. Even in this case there is considered to be improvements which can be made in in-plant control. The concepts of water conservation and by-product recovery are at early stages in most parts of the industry. Therefore, in addition to applying treatment to the total effluent, there is much room for the improvement of water and waste management practices. These will reduce the size of the required treatment systems or improve effluent quality, and in many cases, conserve or yield a product that will help offset or even exceed the costs of the changes.

### In-Plant Control Costs

Two types of in-plant control were recognized in the establishment of effluent limitations. One type was designated good housekeeping and consisted of educating the plant personnel to use good water conservation and solids handling practices, and was not considered to add to the cost of operation. The other type was designated in-plant changes and consisted of actual changes in the plant operation through the incorporation of new or modified equipment.

Improved clean-up and conveying of fish are the areas where improvements can be made in most seafood processing plants. Spring loaded nozzles for washdown hoses are inexpensive but effective in reducing water flow during washdown. There are more sophisticated high-pressure washdown systems currently being manufactured that dramatically reduce water usage. One system provides hot water and cleaning additives at 800 psig with a nozzle flow of about four gpm which enables the operator an effective cleaning capability with minimal water usage. A small plant system with an operating capacity of 20 gpm costs about $5000 for equipment and installation. A medium size plant system providing 35 gpm costs near $10,000, while a large system providing 50 gpm runs near $15,000.

Fluming systems can be replaced by various dry-conveyance systems. Belt conveyor systems are estimated to range between $30 to $60 per linear foot. The pneumatic system shown in Figure 79 of Section VII is estimated to vary in cost from $5000 for a shrimp waste conveyor, which transports 5000 pounds of waste over a distance of 100 feet, to $35,000 to pick up assorted salmon, herring or other solid waste at a rate of 25 tons per hour and convey it 1000 feet. Pneumatic loading systems shown in Figure 80 of Section VII can handle a wide range of raw products and unloading rates. Systems are available that vary in size from five in. to over 12 in. diameter conveying line. A five to six in. system that unloads 15,000 to 18,000 lbs per hour costs around $10,500. Larger systems often are custom built and therefore costs may vary considerably; however, the price will probably range from around $20,000 for an eight in. system to near $38,000 for a 12 in. system.

Table 153 shows the flow and BOD reductions that are estimated to be achievable through "housekeeping" and in-plant control techniques. The annual costs of these modifications are compared with the annual treatment cost savings due to reduced hydraulic load requirements. In most subcategories the in-plant modification costs are more than offset by savings in treatment costs and in some cases a substantial savings can be realized.

## End-of-Pipe Treatment Costs and Design Assumptions

The end-of-pipe treatment costs for each type of system were plotted against flow which was considered to be the most significant variable. Cost versus flow functions (Table 154) were then developed by fitting the points with a piece-wise linear curve, with a break point at 3.16 l/sec (50 gal./min). Second order terms such as in-plant solids handling were then added. Figures 95 and 96 summarize the costs as a function of hydraulic load and removal efficiencies which can be expected for different treatment configurations for a typical plant operating 8 hours per day.

Figures 97 through 101 show the individual capital and operating and maintenance costs developed for screen, air flotation, aerated lagoon and extended aeration treatment systems which were used to estimate the treatment costs for the wastewater from each seafood industry in the contiguous states included in this study. The capital costs of each of these designs are based on 1971 Seattle construction costs. Costs for Alaska based plants are obtained by adding transportation charges to Seattle based equipment costs and by multiplying Seattle based construction costs by a factor of 2.5. Operation and maintenance costs given for each system include labor, power, chemical, and fuel prices. Energy costs are included in the O and M costs and are not considered to be a significant factor except in remote areas of Alaska where biological systems may require heat inputs at certain times of the year. The cost of electrical energy in Kodiak is about 10 times the cost in the "lower 48" and in remote areas of Alaska it is 20 times as much.

## Plant size, treatment efficiency and cost

Table 153 Estimated waste water flow and BOD reductions and costs resulting from in-plant control methods

| Segment | Method | Reduction Flow % | Reduction BOD % | Capital Cost* K$ | Daily O&M Cost* $ | Design Size ton/day |
|---|---|---|---|---|---|---|
| Fish meal w/o solubles unit | add solubles unit | - | 95 | 265 | 200 | 180 |
| Mechanized Salmon | Eliminate in-plant flume | 7 | 2 | 12 | 6 | 40 |
|  | modify washdown system | 15 | 2 | 15 | 20 | 40 |
| Hand-butchered salmon | modify washdown system | 10 | 10 | 16 | 7 | 35 |
| Alaska bottom fish | modify head cut<br>modify wash | 3<br>40 | 5<br>35 | 0<br>2 | 0<br>128 | -<br>53 |
| Conventional bottom fish | reduce fillet table flow<br>modify pre-rinse | 20<br>10 | 15<br>8 | 3<br>1 | 1<br>1 | 43<br>43 |
| Mechanized bottom fish | Eliminate flume | 20 | 20 | 5 | 1 | 49 |
| Sardine canning | Eliminate in-plant flume | 40 | 20 | 3 | 2 | 66 |

Table 153 (Cont'd) Estimated waste water flow and BOD reductions and costs resulting from in-plant control methods

| Segment | Method | Reduction Flow % | Reduction BOD % | Capital Cost* K$ | Daily O&M Cost* $ | Design Size ton/day |
|---|---|---|---|---|---|---|
| Herring filleting | Eliminate flume | 35 | 27 | 25 | 28 | 120 |
| Conventional clams | Optimize equipment flows | 7 | 7 | - | - | - |
| Mechanized clams | High pressure washdown | 12 | 5 | 15 | 13 | 265 |
| Steamed/canned Oysters | High pressure washdown and sweeping | 14 | 30 | 15 | 14 | 8 (final product) |

*Alaska in-plant control costs are 2.5 times the listed costs.

## TABLE 154 TREATMENT SYSTEM COSTS

**Screening**

$<50$ gpm, $\$ = 5000 + 200Q$
$>50$ gpm, $\$ = 12,330 + 53.4Q$
O & M, $\$ = (6 + .021Q)\ HR/16$

**Flotation**

$<50$ gpm, $\$ = 15,000 + 600Q + 17.5\ SS$
$>50$ gpm, $\$ = 35,000 + 200Q + 17.5\ SS$

O & M, $\$ = (20 + 0.145Q)\ HR/16$ with chemicals

**Extended Aeration**

$<50$ gpm, $\$ = (22,000 + 2080Q)\ HR/16$
$>50$ gpm, $\$ = (110,000 + 320Q)\ HR/16$
O & M, $\$ = (10 + .07Q)\ HR/16$

**Aerated Lagoon**

$<50$ gpm, $\$ = (5000 + 900Q)\ HR/16$
$>50$ gpm, $\$ = (46,600 + 66.72Q)\ HR/16$
O & M, $\$ = (7 + 0.032Q)\ HR/16$

Q = flow rate in gpm
SS = pounds dry solids removed per day
HR = hours of operation per day
O & M = daily costs

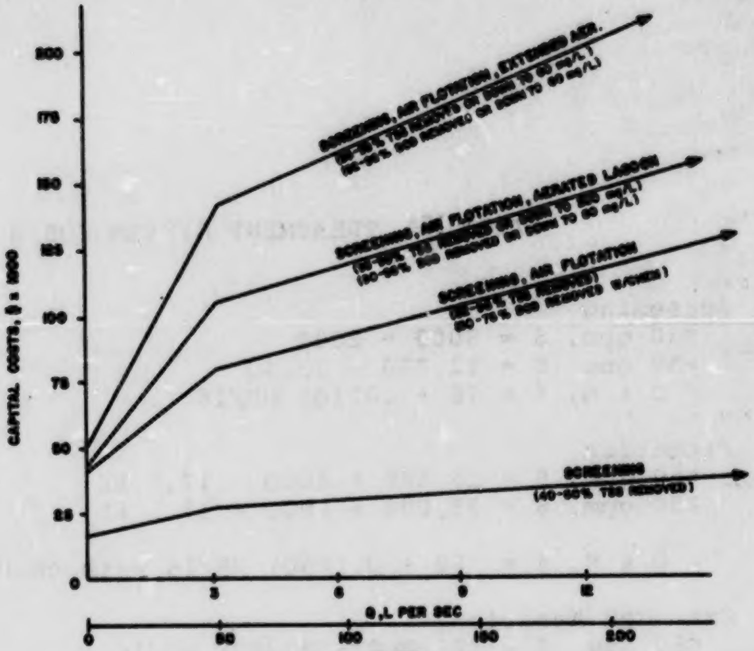


**Figure 95.** Costs and removal efficiencies for alternative treatment systems versus hydraulic loading.

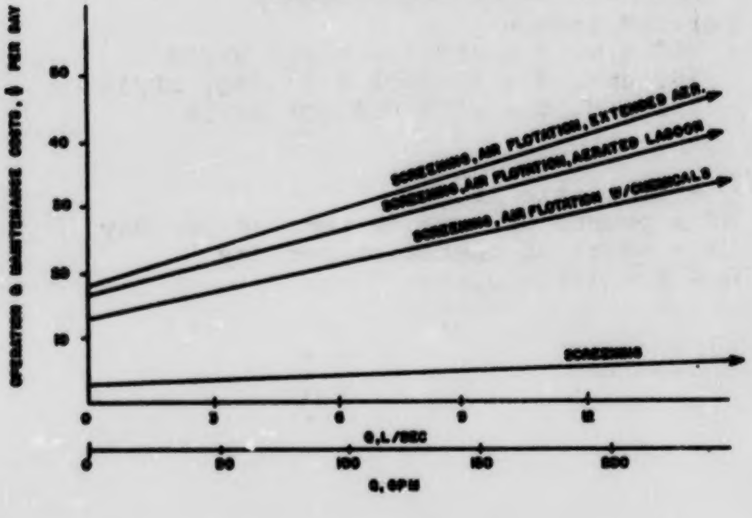


**Figure 96.** Operation and maintenance costs for alternate treatment systems versus hydraulic loading.

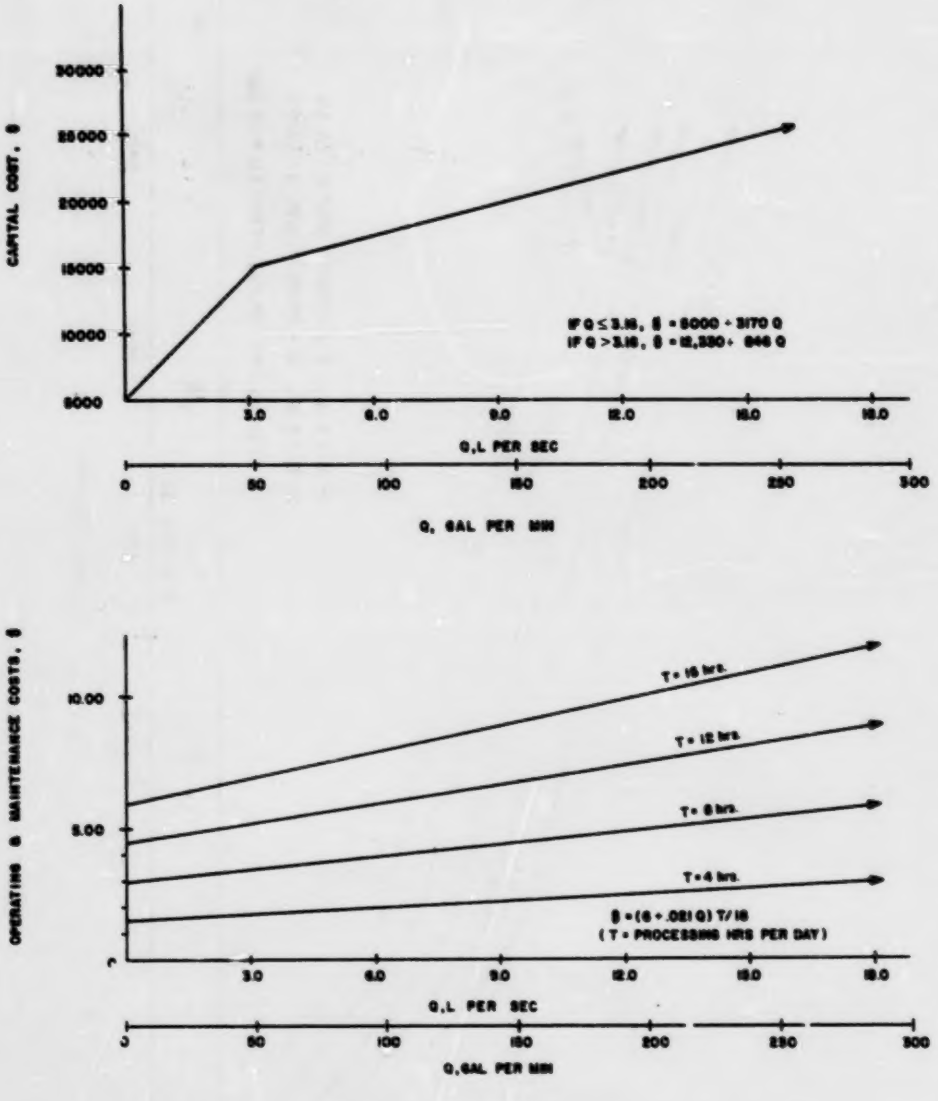


Figure 97. **Capital cost and daily operation and maintenance cost curves for a wastewater screening system**

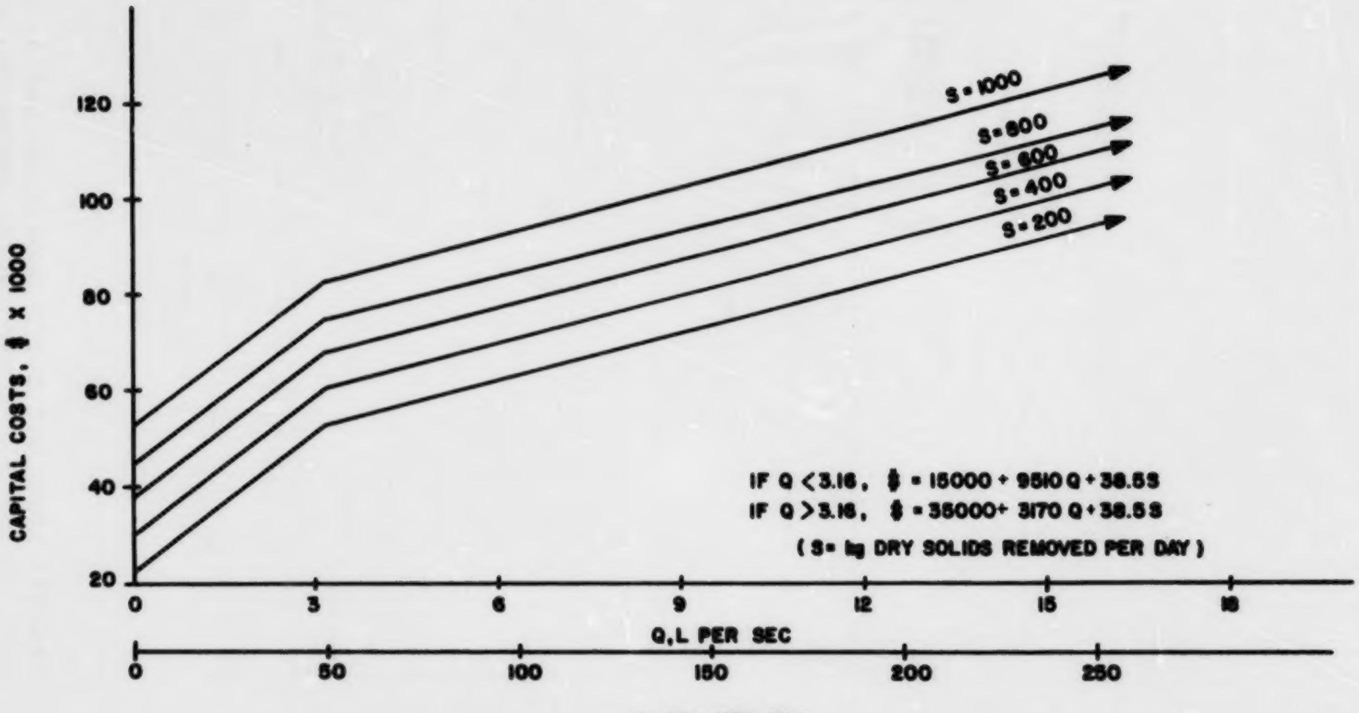
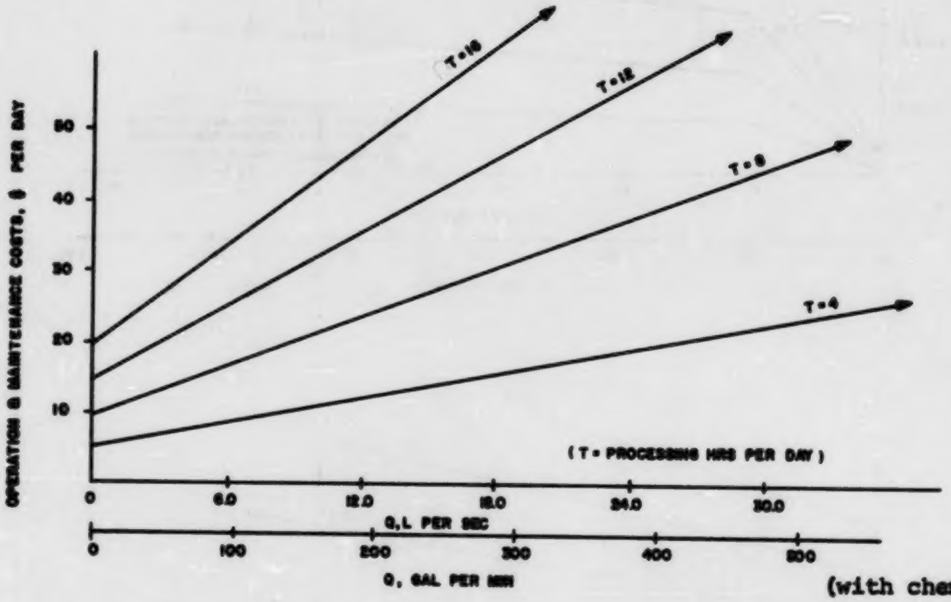


Figure 98. Capital cost curves for a wastewater air flotation system



(with chemicals)

Figure 99. Operation and maintenance costs of an air flotation system.

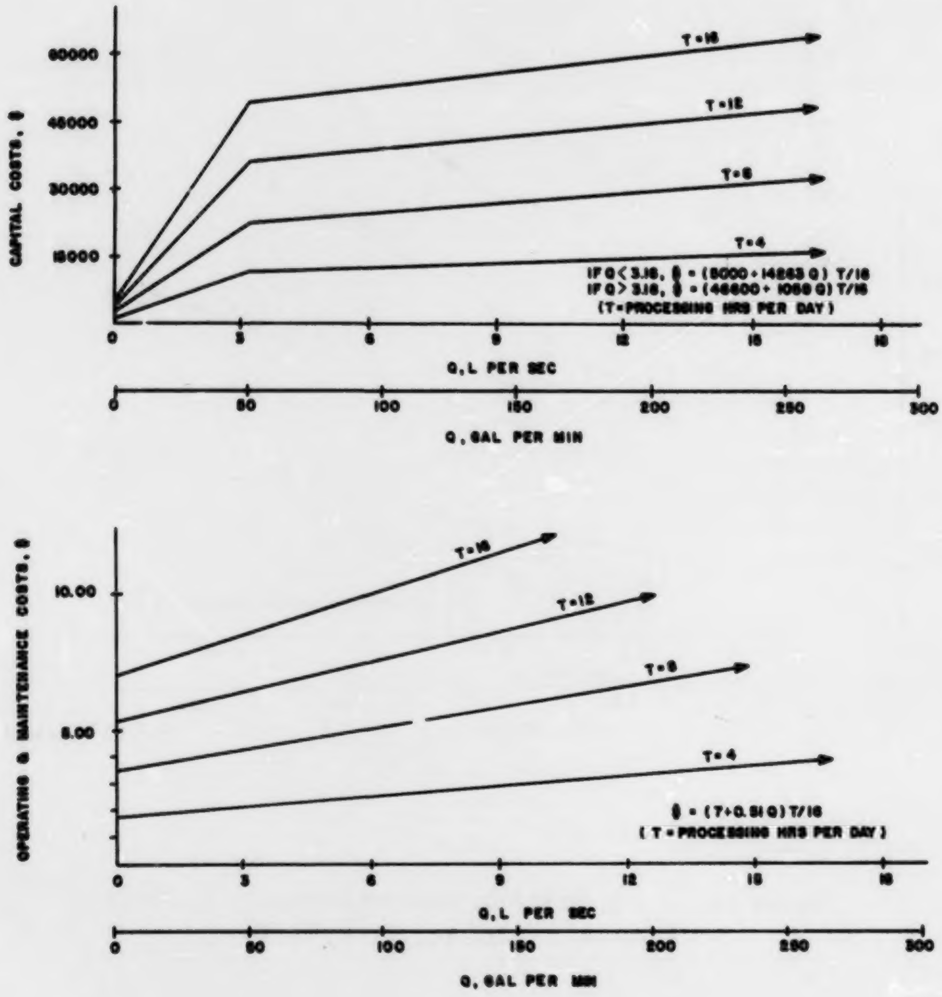


Figure 100 Capital costs and daily operation and maintenance cost curves for an aerated lagoon

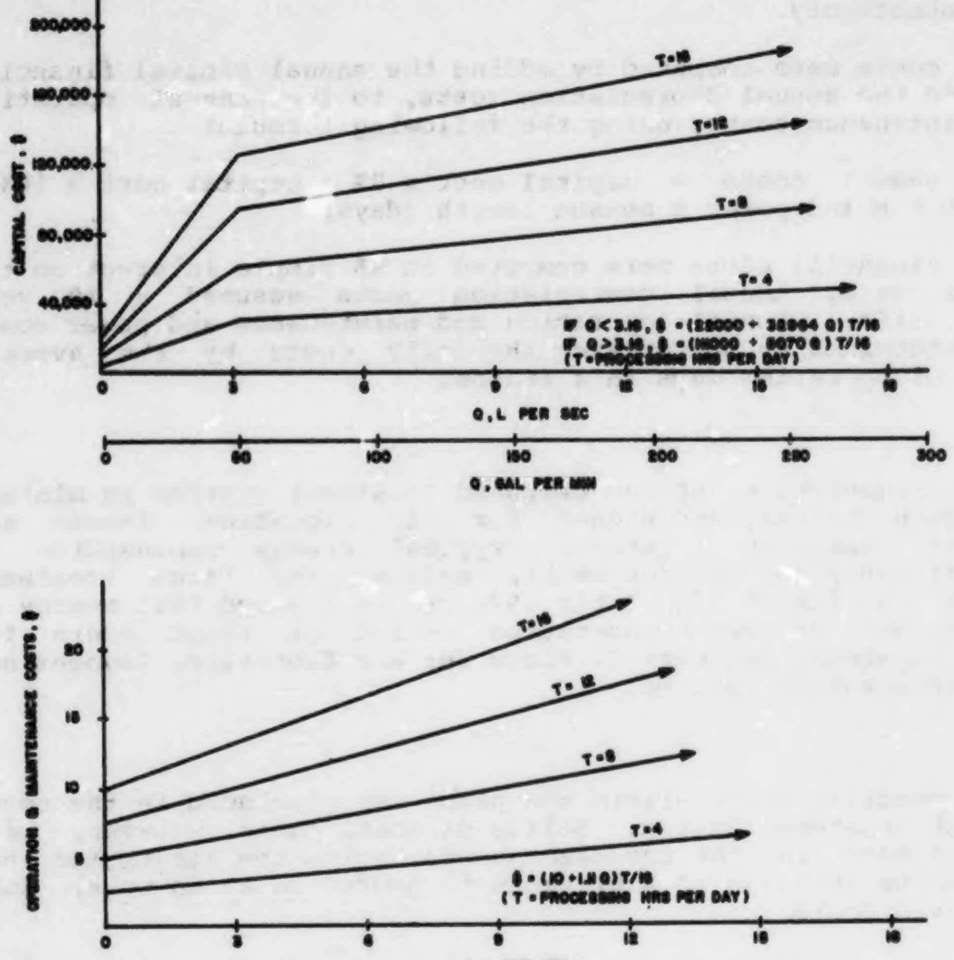


Figure 101. **Capital costs and daily operation and maintenance cost curves for an extended aeration system**

The plant size assumptions used to determine treatment costs for each subcategory are listed at the top of each water effluent treatment cost table (Tables 155 to 196). Equipment was sized for peak operating capacity during a typical processing season. The subcategories were subdivided by size for costing purposes when there was a large plant size variation within the industry as discussed in Section IV. Tables 155 through 196 itemizes the total annual costs for each treatment alternative considered for each subcategory.

Annual costs were computed by adding the annual capital financial costs to the annual depreciation costs, to the annual operating and maintenance costs, using the following formula:

Total annual costs = capital cost x 8% + capital cost x 10% + daily O & M and power x season length (days).

Annual financial costs were computed at 8% simple interest on the capital costs. Annual depreciation costs assumed a 10 year useful life. Annual operation and maintenance and power costs were determined by multiplying the daily costs by the average number of operating days in a season.

## Energy

Energy consumption of the proposed treatment systems is minimal for screen systems, and higher for air flotation, lagoon and extended aeration systems. Typical energy consumption in kilowatt hours per day for small, medium, and large treatment systems is listed in Table 197. It is assumed that energy is consumed over an average operating period of eight hours for screen systems, and over 24 hours for air flotation, lagoons and extended aeration systems.

## Solids

Solids handling costs within the plant were included in the costs for each treatment system. Solids disposal costs, however, were not included in the treatment costs, using the assumption that they can be utilized in a by-products operation at no worse than break-even costs.

Costs for landfill and barging to sea of solids were developed for information purposes and presented graphically by Figure 102. Landfill costs were based on a 20 mile round trip and barging costs were estimated for a 50 mile round trip. It is evident that this type of disposal can be very costly and increased by-product recovery should be emphasized.

The nutritive value of seafood solids and their importance in the world food balance have been discussed in Section VII.

As discussed in Section VII the increased utilization of solids for by-products can reduce wastewater pollution loads. The costs for constructing and operating fish deboning and fish meal facilities were developed and presented for information purposes.

Table 198 lists the costs and potential income from constructing a plant for deboning meat from fish waste, scrap and non-utilized fish with the final product marketed for human consumption. Table 199 lists the costs associated with construction and operation of a fish meal plant. All costs are based on 1973 estimates.

## Air Quality

The maintenance of air quality, in terms of particulates, is unaffected by wastewater treatment facilities except when incineration is practiced. This alternative for solids disposal is not consistent with the conservation of valuable nutrients and is also not cost-effective on a small scale with suitable effluent control.

Odor from landfills can be a problem, and from lagoons and oxidation ponds when not operated or maintained properly. Covers or enclosures can be used in some cases to localize a problem installation.

## Noise

Principal noise sources at treatment facilities are mechanical aerators, air compressors, and pumps. By running air compressors for the diffused air system in activated sludge treatment below their rated critical speed and by providing inlet and exhaust silencers, noise effects can be combated effectively. In no proposed installation would noise levels exceed the guidelines established in the occupational safety and health standards of 1972.

## TABLE 155 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : FISH MEAL WITH SOLUBLES PLANT

| | |
|---|---|
| OPERATING DAY | 22.0 HOURS |
| SEASON | 200.0 DAYS |
| PRODUCTION | 38.6 TON/HR |
| | 35.0 KKG/HR |
| PROCESS FLOW | 1500.0 GPM |
| | 94.7 L/SEC |
| HYDRAULIC LOAD | 2333.8 GAL/TON |
| | 9.7 CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 892. | 202. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 71. | 16. |
| DEPRECIATION @ 10% | 89. | 20. |
| DAILY COSTS($) | | |
| O&M | 158. | 76. |
| POWER | 1. | 1. |
| TOTAL ANNUAL COSTS($1000) | 192. | 52. |

TREATMENT SYSTEMS

1 EXTENDED AERATION
OR
2 AERATED LAGOON

## Table 156 Water effluent treatment costs canned and preserved fish and seafood

Subcategory: Fish meal without solubles plant

| | |
|---|---|
| Operating day | 22.0 hours |
| Season | 200.0 days |
| Production | 8.2 ton/hr |
| | 7.4 kkg/hr |
| Process flow | 100.0 gpm |
| | 6.3 l/sec |
| Hydraulic load | 30.3 gal/ton |
| | 0.1 cu m/kkg |

| Treatment system | 1 | 2 |
|---|---|---|
| Initial investment ($1000) | 564. | 105. |
| Annual costs ($1000) | | |
| Capital costs @ 8% | 45. | 10. |
| Depreciation @ 10% | 56. | 12. |
| Daily costs ($) | | |
| O & M | 48. | 145. |
| Power | 1. | 5. |
| Total annual costs ($1000) | 111. | 51. |

Treatment systems (cumulative)

1. Flotation
2. Evaporator only

NOTE: Treatment 1 for bailwater only; treatment 2 for bailwater and stickwater.

### TABLE 157 WATER EFFLUENT TREATMENT COSTS

### CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : NORTHWEST SALMON CANNING -LARGE

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 85.0 | DAYS |
| PRODUCTION | 5.0 | TON/HR |
| | 4.5 | KKG/HR |
| PROCESS FLOW | 370.0 | GPM |
| | 23.3 | L/SEC |
| HYDRAULIC LOAD | 4477.4 | GAL/TON |
| | 18.7 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 35. | 157. | 271. | 192. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 3. | 13. | 22. | 15. |
| DEPRECIATION @ 10% | 4. | 16. | 27. | 19. |
| DAILY COSTS($) | | | | |
| O&M | 7. | 44. | 62. | 53. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 7. | 32. | 54. | 39. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | FLOTATION -WITH CHEMICALS |
| 3 | EXTENDED AERATION |
| OR | |
| 4 | AERATED LAGOON |

## TABLE 158 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : NORTHWEST SALMON CANNING - SMALL

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 85.0 | DAYS |
| PRODUCTION | 1.9 | TON/HR |
| | 1.7 | KKG/HR |
| PROCESS FLOW | 140.0 | GPM |
| | 8.8 | L/SEC |
| HYDRAULIC LOAD | 4484.5 | GAL/TON |
| | 18.7 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 22. | 90. | 167. | 117. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 2. | 7. | 13. | 9. |
| DEPRECIATION @ 10% | 2. | 9. | 17. | 12. |
| DAILY COSTS($) | | | | |
| O&M | 4. | 25. | 35. | 30. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 4. | 18. | 33. | 24. |

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

## TABLE 159 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : WEST COAST FRESH FROZEN SALMON -LARGE

| | | |
|---|---|---|
| OPERATING DAY | 10.0 | HOURS |
| SEASON | 120.0 | DAYS |
| PRODUCTION | 3.5 | TON/HR |
| | 3.2 | KKG/HR |
| PROCESS FLOW | 50.0 | GPM |
| | 3.2 | L/SEC |
| HYDRAULIC LOAD | 850.9 | GAL/TON |
| | 3.6 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 16. | 62. | 141. | 93. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 1. | 5. | 11. | 7. |
| DEPRECIATION @ 10% | 2. | 6. | 14. | 9. |
| DAILY COSTS($) | | | | |
| O&M | 4. | 21. | 30. | 27. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 4. | 14. | 29. | 20. |

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

## TABLE 160 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : WEST COAST FRESH FROZEN SALMON - SMALL

| | |
|---|---|
| OPERATING DAY | 6.0 HOURS |
| SEASON | 120.0 DAYS |
| PRODUCTION | 1.8 TON/HR |
| | 1.6 KKG/HR |
| PROCESS FLOW | 25.0 GPM |
| | 1.6 L/SEC |
| HYDRAULIC LOAD | 850.9 GAL/TON |
| | 3.6 CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 11. | 41. | 69. | 51. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 0. | 3. | 6. | 4. |
| DEPRECIATION @ 10% | 1. | 4. | 7. | 5. |
| DAILY COSTS($) | | | | |
| O&M | 2. | 11. | 16. | 14. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 2. | 9. | 15. | 11. |

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

## TABLE 161 .WATER EFFLUENT TREATMENT COSTS

### CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : N/W FRESH FROZEN SALMON - LARGE

| | | |
|---|---|---|
| OPERATING DAY | 10.0 | HOURS |
| SEASON | 120.0 | DAYS |
| PRODUCTION | 3.5 | TON/HR |
| | 3.2 | KKG/HR |
| PROCESS FLOW | 50.0 | GPM |
| | 3.2 | L/SEC |
| HYDRAULIC LOAD | 850.9 | GAL/TON |
| | 3.6 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 16. | 48. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 1. | 4. |
| DEPRECIATION @ 10% | 2. | 5. |
| DAILY COSTS($) | | |
| O&M | 4. | 10. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 4. | 10. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | AERATED LAGOON |

## TABLE 162 .WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : N/W FRESH FROZEN SALMON - LARGE

| | |
|---|---|
| OPERATING DAY | 10.0 HOURS |
| SEASON | 120.0 DAYS |
| PRODUCTION | 3.5 TON/HR |
| | 3.2 KKG/HR |
| PROCESS FLOW | 50.0 GPM |
| | 3.2 L/SEC |
| HYDRAULIC LOAD | 850.9 GAL/TON |
| | 3.6 CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 16. | 95. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 1. | 8. |
| DEPRECIATION @ 10% | 2. | 10. |
| DAILY COSTS($) | | |
| O&M | 4. | 13. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 4. | 19. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | EXTENDED AERATION |

## TABLE 163 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : N/W FRESH FROZEN SALMON - SMALL

| | | |
|---|---|---|
| OPERATING DAY | 6.0 | HOURS |
| SEASON | 120.0 | DAYS |
| PRODUCTION | 1.8 | TON/HR |
| | 1.6 | KKG/HR |
| PROCESS FLOW | 25.0 | GPM |
| | 1.6 | L/SEC |
| HYDRAULIC LOAD | 850.9 | GAL/TON |
| | 3.6 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 11. | 21. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 0. | 2. |
| DEPRECIATION @ 10% | 1. | 2. |
| DAILY COSTS($) | | |
| O&M | 2. | 5. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 2. | 5. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | AERATED LAGOON |

## TABLE 164 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : N/W FRESH FROZEN SALMON - SMALL

| | | |
|---|---|---|
| OPERATING DAY | 6.0 | HOURS |
| SEASON | 120.0 | DAYS |
| PRODUCTION | 1.8 | TON/HR |
| | 1.6 | KKG/HR |
| PROCESS FLOW | 25.0 | GPM |
| | 1.6 | L/SEC |
| HYDRAULIC LOAD | 850.9 | GAL/TON |
| | 3.6 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 11. | 39. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 0. | 3. |
| DEPRECIATION @ 10% | 1. | 4. |
| DAILY COSTS($) | | |
| O&M | 2. | 7. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 2. | 8. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | EXTENDED AERATION |

## TABLE 165 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : NONALASKAN CONV. BOTTOM FISH - LARGE

| | |
|---|---|
| OPERATING DAY | 10.0 HOURS |
| SEASON | 200.0 DAYS |
| PRODUCTION | 4.3 TON/HR |
| | 3.9 KKG/HR |
| PROCESS FLOW | 100.0 GPM |
| | 6.3 L/SEC |
| HYDRAULIC LOAD | 1396.3 GAL/TON |
| | 5.8 CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 19. | 77. | 166. | 110. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 2. | 6. | 13. | 9. |
| DEPRECIATION @ 10% | 2. | 8. | 17. | 11. |
| DAILY COSTS($) | | | | |
| O&M | 5. | 27. | 37. | 33. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 5. | 20. | 38. | 27. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | FLOTATION - WITH CHEMICALS |
| 3 | EXTENDED AERATION |
| OR | |
| 4 | AERATED LAGOON |

## TABLE 166 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : NONALASKAN CONV. BOTTOM FISH - LARGE

| | | |
|---|---|---|
| OPERATING DAY | 10.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 4.3 | TON/HR |
| | 3.9 | KKG/HR |
| PROCESS FLOW | 100.0 | GPM |
| | 6.3 | L/SEC |
| HYDRAULIC LOAD | 1396.3 | GAL/TON |
| | 5.8 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 19. | 53. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 2. | 4. |
| DEPRECIATION @ 10% | 2. | 5. |
| DAILY COSTS($) | | |
| O&M | 5. | 11. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 5. | 12. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | AERATED LAGOON |

## TABLE 167. WATER EFFLUENT TREATMENT COSTS

### CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : NONALASKAN CONV. BOTTOM FISH -MEDIUM

| | | |
|---|---|---|
| OPERATING DAY | 9.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 2.5 | TON/HR |
| | 2.3 | KKG/HR |
| PROCESS FLOW | 60.0 | GPM |
| | 3.8 | L/SEC |
| HYDRAULIC LOAD | 1420.6 | GAL/TON |
| | 5.9 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 17. | 65. | 138. | 94. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 1. | 5. | 11. | 8. |
| DEPRECIATION @ 10% | 2. | 7. | 14. | 9. |
| DAILY COSTS($) | | | | |
| O&M | 4. | 20. | 28. | 25. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 4. | 16. | 31. | 23. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | FLOTATION - WITH CHEMICALS |
| 3 | EXTENDED AERATION |
| OR | |
| 4 | AERATED LAGOON |

## TABLE 168 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

## SUBCATEGORY: NONALASKAN CONV. BOTTOM FISH - MEDIUM

| | |
|---|---|
| OPERATING DAY | 9.0 HOURS |
| SEASON | 200.0 DAYS |
| PRODUCTION | 2.5 TON/HR |
| | 2.3 KKG/HR |
| PROCESS FLOW | 60.0 GPM |
| | 3.8 L/SEC |
| HYDRAULIC LOAD | 1420.6 GAL/TON |
| | 5.9 CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 17. | 46. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 1. | 4. |
| DEPRECIATION @ 10% | 2. | 5. |
| DAILY COSTS($) | | |
| O&M | 4. | 9. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 4. | 10. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | AERATED LAGOON |

## TABLE 169 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : NONALASKAN CONV. BOTTOM FISH - SMALL

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 1.3 | TON/HR |
| | 1.2 | KKG/HR |
| PROCESS FLOW | 30.0 | GPM |
| | 1.9 | L/SEC |
| HYDRAULIC LOAD | 1361.4 | GAL/TON |
| | 5.7 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 12. | 46. | 88. | 62. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 0. | 4. | 7. | 5. |
| DEPRECIATION @ 10% | 1. | 5. | 9. | 6. |
| DAILY COSTS($) | | | | |
| O&M | 3. | 15. | 22. | 19. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 3. | 12. | 21. | 16. |

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

## TABLE 170 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

## SUBCATEGORY: NONALASKAN CONV. BOTTOM FISH - SMALL

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 1.3 | TON/HR |
| | 1.2 | KKG/HR |
| PROCESS FLOW | 30.0 | GPM |
| | 1.9 | L/SEC |
| HYDRAULIC LOAD | 1361.4 | GAL/TON |
| | 5.7 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 12. | 28. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 0. | 2. |
| DEPRECIATION @ 10% | 1. | 3. |
| DAILY COSTS($) | | |
| O&M | 3. | 7. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 3. | 7. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | AERATED LAGOON |

## TABLE 171.WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : NONALASKAN MECH. BOTTOM FISH - LARGE

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 180.0 | DAYS |
| PRODUCTION | 6.1 | TON/HR |
| | 5.5 | KKG/HR |
| PROCESS FLOW | 180.0 | GPM |
| | 11.4 | L/SEC |
| HYDRAULIC LOAD | 1782.2 | GAL/TON |
| | 7.4 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 24. | 104. | 188. | 134. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 2. | 8. | 15. | 11. |
| DEPRECIATION @ 10% | 2. | 10. | 19. | 13. |
| DAILY COSTS($) | | | | |
| O&M | 5. | 28. | 39. | 34. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 5. | 24. | 41. | 31. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | FLOTATION - WITH CHEMICALS |
| 3 | EXTENDED AERATION |
| OR | |
| 4 | AERATED LAGOON |

## TABLE 172 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : NONALASKAN MECH. BOTTOM FISH -SMALL

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 180.0 | DAYS |
| PRODUCTION | 1.0 | TON/HR |
| | 0.9 | KKG/HR |
| PROCESS FLOW | 50.0 | GPM |
| | 3.1 | L/SEC |
| HYDRAULIC LOAD | 3025.3 | GAL/TON |
| | 12.6 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 16. | 63. | 126. | 88. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 1. | 5. | 10. | 7. |
| DEPRECIATION @ 10% | 2. | 6. | 13. | 9. |
| DAILY COSTS($) | | | | |
| O&M | 4. | 17. | 24. | 21. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 4. | 15. | 28. | 20. |

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

## TABLE 173. WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : CONVENTIONAL CLAMS - LARGE

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 5.7 | TON/HR |
| | 5.2 | KKG/HR |
| PROCESS FLOW | 120.0 | GPM |
| | 7.6 | L/SEC |
| HYDRAULIC LOAD | 1256.7 | GAL/TON |
| | 5.2 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 21. | 98. | 126. | 96. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 2. | 8. | 10. | 4. |
| DEPRECIATION @ 10% | 2. | 10. | 13. | 5. |
| DAILY COSTS($) | | | | |
| O&M | 4. | 23. | 28. | 9. |
| POWER | 1. | 2. | 3. | 2. |
| TOTAL ANNUAL COSTS($1000) | 5. | 23. | 29. | 11. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | FLOTATION - WITH CHEMICALS |
| 3 | AERATED LAGOON |
| 4 | SCREENING + EXTENDED AERATION |

## TABLE 174 . WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

## SUBCATEGORY : CONVENTIONAL CLAMS - SMALL

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 3.4 | TON/HR |
| | 3.1 | KKG/HR |
| PROCESS FLOW | 70.0 | GPM |
| | 4.4 | L/SEC |
| HYDRAULIC LOAD | 1229.6 | GAL/TON |
| | 5.1 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 18. | 78. | 144. | 104. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 1. | 6. | 12. | 8. |
| DEPRECIATION @ 10% | 2. | 8. | 14. | 10. |
| DAILY COSTS($) | | | | |
| O&M | 4. | 19. | 26. | 23. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 4. | 18. | 32. | 24. |

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

## TABLE 175 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : CONVENTIONAL CLAMS - SMALL

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 3.4 | TON/HR |
| | 3.1 | KKG/HR |
| PROCESS FLOW | 70.0 | GPM |
| | 4.4 | L/SEC |
| HYDRAULIC LOAD | 1229.6 | GAL/TON |
| | 5.1 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 18. | 43. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 1. | 3. |
| DEPRECIATION @ 10% | 2. | 4. |
| DAILY COSTS($) | | |
| O&M | 4. | 8. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 4. | 10. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | AERATED LAGOON |

## TABLE 176 WATER EFFLUENT TREATMENT COSTS

### CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : CONVENTIONAL CLAMS - SMALL

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 3.4 | TON/HR |
| | 3.1 | KKG/HR |
| PROCESS FLOW | 70.0 | GPM |
| | 4.4 | L/SEC |
| HYDRAULIC LOAD | 1229.6 | GAL/TON |
| | 5.1 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 18. | 84. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 1. | 7. |
| DEPRECIATION @ 10% | 2. | 8. |
| DAILY COSTS($) | | |
| O&M | 4. | 11. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 4. | 18. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | EXTENDED AERATION |

## TABLE 177 . WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : MECHANIZED CLAMS - LARGE

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 33.1 | TON/HR |
| | 30.0 | KKG/HR |
| PROCESS FLOW | 900.0 | GPM |
| | 56.8 | L/SEC |
| HYDRAULIC LOAD | 1633.6 | GAL/TON |
| | 6.8 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 66. | 331. | 530. | 385. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 5. | 27. | 42. | 31. |
| DEPRECIATION @ 10% | 7. | 33. | 53. | 38. |
| DAILY COSTS($) | | | | |
| O&M | 12. | 88. | 124. | 106. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 15. | 78. | 121. | 91. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | FLOTATION - WITH CHEMICALS |
| 3 | EXTENDED AERATION |
| OR | |
| 4 | AERATED LAGOON |

## TABLE 178 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

## SUBCATEGORY : MECHANIZED CLAMS - LARGE

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 33.1 | TON/HR |
| | 30.0 | KKG/HR |
| PROCESS FLOW | 900.0 | GPM |
| | 56.8 | L/SEC |
| HYDRAULIC LOAD | 1633.6 | GAL/TON |
| | 6.8 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 66. | 120. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 5. | 10. |
| DEPRECIATION @ 10% | 7. | 12. |
| DAILY COSTS($) | | |
| O&M | 12. | 30. |
| POWER | 1. | 3. |
| TOTAL ANNUAL COSTS($1000) | 15. | 28. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | AERATED LAGOON |

# TABLE 179 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : MECHANIZED CLAMS - LARGE

| | |
|---|---|
| OPERATING DAY | 8.0 HOURS |
| SEASON | 200.0 DAYS |
| PRODUCTION | 33.1 TON/HR |
| | 30.0 KKG/HR |
| PROCESS FLOW | 900.0 GPM |
| | 56.8 L/SEC |
| HYDRAULIC LOAD | 1633.6 GAL/TON |
| | 6.8 CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 66. | 265. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 5. | 21. |
| DEPRECIATION @ 10% | 7. | 27. |
| DAILY COSTS($) | | |
| O&M | 12. | 49. |
| POWER | 1. | 3. |
| TOTAL ANNUAL COSTS($1000) | 15. | 58. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | EXTENDED AERATION |

## TABLE 180 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : MECHANIZED CLAMS - SMALL

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 9.8 | TON/HR |
| | 8.9 | KKG/HR |
| PROCESS FLOW | 270.0 | GPM |
| | 17.0 | L/SEC |
| HYDRAULIC LOAD | 1652.0 | GAL/TON |
| | 6.9 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 29. | 133. | 231. | 166. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 2. | 11. | 19. | 13. |
| DEPRECIATION @ 10% | 3. | 13. | 23. | 17. |
| DAILY COSTS($) | | | | |
| O&M | 6. | 35. | 50. | 43. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 7. | 31. | 52. | 39. |

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

## TABLE 181 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

## SUBCATEGORY : MECHANIZED CLAMS - SMALL

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 9.8 | TON/HR |
| | 8.9 | KKG/HR |
| PROCESS FLOW | 270.0 | GPM |
| | 17.0 | L/SEC |
| HYDRAULIC LOAD | 1652.0 | GAL/TON |
| | 6.9 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 29. | 62. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 2. | 5. |
| DEPRECIATION @ 10% | 3. | 6. |
| DAILY COSTS($) | | |
| O&M | 6. | 14. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 7. | 14. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | AERATED LAGOON |

## TABLE 182 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : MECHANIZED CLAMS - SMALL

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 9.8 | TON/HR |
| | 8.9 | KKG/HR |
| PROCESS FLOW | 270.0 | GPM |
| | 17.0 | L/SEC |
| HYDRAULIC LOAD | 1652.0 | GAL/TON |
| | 6.9 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 29. | 128. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 2. | 10. |
| DEPRECIATION @ 10% | 3. | 13. |
| DAILY COSTS($) | | |
| O&M | 6. | 20. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 7. | 27. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | EXTENDED AERATION |

## TABLE 183 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : PACIFIC HAND SHUCKED OYSTER - LARGE

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 110.0 | DAYS |
| PRODUCTION | 0.4 | TON/HR |
| | 0.4 | KKG/HR |
| PROCESS FLOW | 115.0 | GPM |
| | 7.3 | L/SEC |
| HYDRAULIC LOAD | 15655.8 | GAL/TON |
| | 65.3 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 20. | 94. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 2. | 7. |
| DEPRECIATION @ 10% | 2. | 9. |
| DAILY COSTS($) | | |
| O&M | 4. | 13. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 4. | 19. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | EXTENDED AERATION |

# TABLE 184 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

## SUBCATEGORY : PACIFIC HAND SHUCKED OYSTER - MEDIUM

| | |
|---|---|
| OPERATING DAY | 8.0 HOURS |
| SEASON | 110.0 DAYS |
| PRODUCTION | 0.2 TON/HR<br>0.2 KKG/HR |
| PROCESS FLOW | 50.0 GPM<br>3.2 L/SEC |
| HYDRAULIC LOAD | 13613.7 GAL/TON<br>56.8 CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 16. | 79. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 1. | 6. |
| DEPRECIATION @ 10% | 2. | 8. |
| DAILY COSTS($) | | |
| O&M | 4. | 10. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 3. | 16. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | EXTENDED AERATION |

## TABLE 185 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : PACIFIC HAND SHUCKED OYSTER - SMALL

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 90.0 | DAYS |
| PRODUCTION | 0.0 | TON/HR |
| | 0.0 | KKG/HR |
| PROCESS FLOW | 13.0 | GPM |
| | 0.8 | L/SEC |
| HYDRAULIC LOAD | 17697.8 | GAL/TON |
| | 73.9 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 8. | 33. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 0. | 3. |
| DEPRECIATION @ 10% | 0. | 3. |
| DAILY COSTS($) | | |
| O&M | 3. | 9. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 2. | 7. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | EXTENDED AERATION |

## TABLE 186 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY EASTERN HAND SHUCKED OYSTERS - MEDIUM

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 200.0 | DAYS |
| PRODUCTION | 0.2 | TON/HR |
| | 0.2 | KKG/HR |
| PROCESS FLOW | 25.0 | GPM |
| | 1.6 | L/SEC |
| HYDRAULIC LOAD | 8508.6 | GAL/TON |
| | 35.5 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 |
|---|---|---|---|
| INITIAL INVESTMENT($1000) | 11. | 41. | 78. |
| ANNUAL COSTS($1000) | | | |
| CAPITAL COSTS @ 8% | 1. | 3. | 6. |
| DEPRECIATION @ 10% | 1. | 4. | 8. |
| DAILY COSTS($) | | | |
| O&M | 3. | 13. | 19. |
| POWER | 1. | 2. | 3. |
| TOTAL ANNUAL COSTS($1000) | 3. | 11. | 19. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | FLOTATION - WITH CHEMICALS |
| 3 | EXTENDED AERATION |

## TABLE 187 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : STEAMED OR CANNED OYSTERS

| | | |
|---|---|---|
| OPERATING DAY | 8.0 | HOURS |
| SEASON | 110.0 | DAYS |
| PRODUCTION | 0.9 | TON/HR |
| | 0.8 | KKG/HR |
| PROCESS FLOW | 220.0 | GPM |
| | 13.9 | L/SEC |
| HYDRAULIC LOAD | 14975.1 | GAL/TON |
| | 62.5 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 26. | 123. | 213. | 153. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 2. | 10. | 17. | 12. |
| DEPRECIATION @ 10% | 3. | 12. | 21. | 15. |
| DAILY COSTS($) | | | | |
| O&M | 5. | 31. | 44. | 38. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 5. | 26. | 44. | 32. |

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

## TABLE 188 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : SARDINE CANNING - LARGE

| | |
|---|---|
| OPERATING DAY | 8.0 HOURS |
| SEASON | 60.0 DAYS |
| PRODUCTION | 8.3 TON/HR |
| | 7.5 KKG/HR |
| PROCESS FLOW | 240.0 GPM |
| | 15.1 L/SEC |
| HYDRAULIC LOAD | 1742.6 GAL/TON |
| | 7.3 CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 28. | 125. | 218. | 156. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 2. | 10. | 17. | 12. |
| DEPRECIATION @ 10% | 3. | 12. | 22. | 16. |
| DAILY COSTS($) | | | | |
| O&M | 6. | 33. | 46. | 40. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 5. | 25. | 42. | 31. |

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

## TABLE 189.. WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

## SUBCATEGORY : SARDINE CANNING - MEDIUM

| | |
|---|---|
| OPERATING DAY | 8.0 HOURS |
| SEASON | 60.0 DAYS |
| PRODUCTION | 5.5 TON/HR |
| | 5.0 KKG/HR |
| PROCESS FLOW | 160.0 GPM |
| | 10.1 L/SEC |
| HYDRAULIC LOAD | 1742.6 GAL/TON |
| | 7.3 CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 23. | 99. | 180. | 128. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 2. | 8. | 14. | 10. |
| DEPRECIATION @ 10% | 2. | 10. | 18. | 13. |
| DAILY COSTS($) | | | | |
| O&M | 5. | 26. | 37. | 32. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 4. | 20. | 35. | 25. |

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

## TABLE 190 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : SARDINE CANNING - SMALL

| | |
|---|---|
| OPERATING DAY | 8.0 HOURS |
| SEASON | 60.0 DAYS |
| PRODUCTION | 2.1 TON/HR |
| | 1.9 KKG/HR |
| PROCESS FLOW | 60.0 GPM |
| | 3.8 L/SEC |
| HYDRAULIC LOAD | 1719.6 GAL/TON |
| | 7.2 CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| INITIAL INVESTMENT($1000) | 17. | 68. | 132. | 93. |
| ANNUAL COSTS($1000) | | | | |
| CAPITAL COSTS @ 8% | 1. | 5. | 11. | 7. |
| DEPRECIATION @ 10% | 2. | 7. | 13. | 9. |
| DAILY COSTS($) | | | | |
| O&M | 4. | 18. | 25. | 22. |
| POWER | 1. | 2. | 3. | 3. |
| TOTAL ANNUAL COSTS($1000) | 3. | 13. | 25. | 18. |

TREATMENT SYSTEMS
(CUMULATIVE)

1 SCREENING
2 FLOTATION - WITH CHEMICALS
3 EXTENDED AERATION
OR
4 AERATED LAGOON

## TABLE 191 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : Non-Alaskan Scallops

| | | |
|---|---|---|
| OPERATING DAY | 12.0 | HOURS |
| SEASON | 60.0 | DAYS |
| PRODUCTION | 1.7 | TON/HR |
| | 1.5 | KKG/HR |
| PROCESS FLOW | 55.0 | GPM |
| | 3.5 | L/SEC |
| HYDRAULIC LOAD | 1996.7 | GAL/TON |
| | 8.3 | CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 |
|---|---|---|---|
| INITIAL INVESTMENT($1000) | 17 | 63 | 113 |
| ANNUAL COSTS($1000) | | | |
| CAPITAL COSTS @ 8% | 1 | 5 | 9 |
| DEPRECIATION @ 10% | 2 | 6 | 12 |
| DAILY COSTS($) | | | |
| O&M | 5. | 26 | 31. |
| POWER | 1. | 2. | 3. |
| TOTAL ANNUAL COSTS($1000) | 4 | 12 | 23 |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | FLOTATION |
| 3 | SCREENING AND EXTENDED AERATION |

## TABLE 192 WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : NONALASKAN HERRING FILLETING

| | |
|---|---|
| OPERATING DAY | 12.0 HOURS |
| SEASON | 100.0 DAYS |
| PRODUCTION | 14.9 TON/HR |
| | 13.5 KKG/HR |
| PROCESS FLOW | 520.0 GPM |
| | 32.8 L/SEC |
| HYDRAULIC LOAD | 2097.5 GAL/TON |
| | 8.8 CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 | 3 |
|---|---|---|---|
| INITIAL INVESTMENT($1000) | 44. | 313. | 520. |
| ANNUAL COSTS($1000) | | | |
| CAPITAL COSTS @ 8% | 4. | 25. | 42. |
| DEPRECIATION @ 10% | 4. | 31. | 52. |
| DAILY COSTS($) | | | |
| O&M | 13. | 84. | 119. |
| POWER | 1. | 2. | 3. |
| TOTAL ANNUAL COSTS($1000) | 10. | 65. | 106. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | SCREENING |
| 2 | FLOTATION - WITH CHEMICALS |
| 3 | EXTENDED AERATION |

## TABLE 193. WATER EFFLUENT TREATMENT COSTS

## CANNED AND PRESERVED FISH AND SEAFOOD

### SUBCATEGORY : **ABALONE**

| | |
|---|---|
| OPERATING DAY | 8.0 HOURS |
| SEASON | 200.0 DAYS |
| PRODUCTION | 0.9 TON/HR |
| | 0.8 KKG/HR |
| PROCESS FLOW | 10.0 GPM |
| | 0.6 L/SEC |
| HYDRAULIC LOAD | 680.7 GAL/TON |
| | 2.8 CU M/KKG |

| TREATMENT SYSTEM | 1 | 2 |
|---|---|---|
| INITIAL INVESTMENT($1000) | 26. | 47. |
| ANNUAL COSTS($1000) | | |
| CAPITAL COSTS @ 8% | 2. | 4. |
| DEPRECIATION @ 10% | 3. | 5. |
| DAILY COSTS($) | | |
| O&M | 10. | 15. |
| POWER | 1. | 2. |
| TOTAL ANNUAL COSTS($1000) | 7. | 12. |

TREATMENT SYSTEMS
(CUMULATIVE)

| | |
|---|---|
| 1 | FLOTATION WITHOUT CHEMICALS |
| 2 | EXTENDED AERATION |

## Table 194

## Incremental Water Effluent Treatment Costs for Alaskan Segments - Alaskan Salmon Canning

| | | |
|---|---|---|
| Operating Day | 18 hrs | 18 hrs |
| Season | 42 days | 42 days |
| Production | 8.3 ton/hr | 5 ton/hr |
| | 7.5 kkg/hr | 4.5 kkg/hr |
| Process Flow | 600 gpm | 370 gpm |
| | 37.9 L/sec | 23.4 L/sec |
| Hydraulic Load | 4356 gal/ton | 4477 gal/ton |
| | 18.2 cu m/kkg | 18.7 cu m/kkg |
| Treatment System | | |
| Grinding | | |
| Capital $ | 54,000 | 45,000 |
| O & M $/day | 100 | 90 |
| Screening | | |
| Capital $ | 64,000 | 51,000 |
| O & M $/day | 120 | 100 |
| Barging | | |
| Capital $ | 82,000 | 69,000 |
| O & M $/day | 320 | 270 |
| Flotation - with chemicals* | | |
| Capital $ | 501,000 | 329,000 |
| O & M $/day | 130 | 90 |

*Based on estimated Seattle construction costs multiplied by 2.5 plus estimated Seattle equipment costs and transportation

## Table 194 (cont.)

### Incremental Water Effluent Treatment Costs for Alaskan Segments - Alaskan Hand-Butchered Salmon

| | | |
|---|---|---|
| Operating Day | 12 hrs | 12 hrs |
| Season | 90 days | 90 days |
| Production | 4.4 ton/hr<br>4.0 kkg/hr | 1.1 ton/hr<br>1.04 kkg/hr |
| Process Flow | 90 gpm<br>5.7 L/sec | 25 gpm<br>1.7 L/sec |
| Hydraulic Load | 1225 gal/ton<br>5.1 cu m/kkg | 1361 gal/ton<br>5.7 cu m/kkg |
| Treatment System | | |
| Grinding | | |
| Capital $ | 31,000 | 24,000 |
| O & M $/day | 50 | 45 |
| Screening | | |
| Capital $ | 32,000 | 24,000 |
| O & M $/day | 45 | 35 |
| Barging | | |
| Capital $ | 47,000 | 32,000 |
| O & M $/day | 150 | 130 |
| Flotation - with chemicals* | | |
| Capital $ | 95,000 | 53,000 |
| O & M $/day | 35 | 25 |

*Based on estimated Seattle construction costs multiplied by 2.5 plus estimated Seattle equipment costs and transportation

## Table 195

## Incremental Water Effluent Treatment Costs for Alaskan Segments - Alaskan Bottom Fish

| | | |
|---|---|---|
| Operating Day | 8 hrs | 8 hrs |
| Season | 100 days | 100 days |
| Production | 13.2 ton/hr | 1.7 ton/hr |
| | 12.0 kkg/hr | 1.5 kkg/hr |
| Process Flow | 200 gpm | 16 gpm |
| | 12.6 l/sec | 1.0 l/sec |
| Hydraulic Load | 908 gal/ton | 581 gal/ton |
| | 3.8 cu m/kkg | 2.4 cu m/kkg |

| | | |
|---|---|---|
| Treatment System | | |
| Grinding | | |
| Capital $ | 38,000 | 20,000 |
| O & M $/day | 60 | 50 |
| Screening | | |
| Capital $ | 41,000 | 21,000 |
| O & M $/day | 50 | 30 |
| Barging | | |
| Capital $ | 57,000 | 34,000 |
| O & M $/day | 140 | 120 |
| Flotation - with chemicals* | | |
| Capital $ | 137,000 | 44,000 |
| O & M $/day | 25 | 11 |

*Based on estimated Seattle construction costs multiplied by 2.5 plus estimated Seattle equipment costs and transportation

## Table 19C

## Incremental Water Effluent Treatment Costs for Alaskan Segments - Alaskan Herring Filleting

| | |
|---|---|
| Operating Day | 12 hours |
| Season | 100 days |
| Production | 14.9 ton/hr<br>13.5 kkg/hr |
| Process Flow | 520 gpm<br>32.8 l/sec |
| Hydraulic Load | 2098 gal/ton<br>8.8 cu m/kkg |

---

| Treatment System | |
|---|---|
| Grinding | |
| Capital $ | 57,000 |
| O&M $/day | 70 |
| Screening | |
| Capital $ | 60,000 |
| O&M $/day | 75 |
| Barging | |
| Capital $ | 119,000 |
| O&M $/day | 290 |
| Flotation-with chemicals* | |
| Capital $ | 469,000 |
| O&M $/day | 75 |

*Based on estimated Seattle construction costs multiplied by 2.5 plus estimated Seattle equipment costs and transportation

Table 197 Energy consumption of alternative treatment systems.

| Treatment System | Energy consumption KWH/day | | |
|---|---|---|---|
| | Small | Medium | Large |
| Screen | 16 | 64 | 160 |
| Air flotation | 180 | 450 | 1200 |
| Aerated lagoon | 200 | 700 | 1700 |
| Extended aeration | 240 | 900 | 2000 |

Table 198 Cost of construction and operation of a fish deboning plant.

Capital Investment Costs:

| | | |
|---|---|---|
| 1. | Processing equipment | $213,800 |
| 2. | Construction and installation | 26,000 |
| 3. | Miscellaneous | 21,290 |
| | | $261,090 |

Operating cost and income - no charge for waste & trimmings.

| | Production Rates | | |
|---|---|---|---|
| Item | 2000 lbs/day | 4000 lbs/day | 8000 lbs/day |
| Raw material cost | $190.00 | $380.00 | $760.00 |
| Processing cost | 370.00 | 370.00 | 370.00 |
| Freezing @ .05/lb | 100.00 | 200.00 | 400.00 |
| Packaging @ .01/lb | 20.00 | 40.00 | 80.00 |
| Daily operating cost | $680.00 | $990.00 | $1610.00 |
| Operating cost per lb | 34.0¢ | 24.8¢ | 20.1¢ |
| Selling price (FOB plant) | 40.0¢ | 40.0¢ | 40.0¢ |
| Total daily sales | $800.00 | $1600.00 | $3200.00 |
| Daily operating cost | 685.00 | 990.00 | 1610.00 |
| Daily operating income | $115.00 | $ 610.00 | $1590.00 |

Table 199. Capital and operating costs for batch and continuous fish meal facilities.

| Type of plant | Capacity (input) | Equipment costs K$ |
|---|---|---|
| Batch | 1/2 ton/hour | 20 - 25 |
| Batch | 3/4 ton/hour | 25 - 30 |
| Semi-continuous | 1/2 ton/hour | 40 - 50 |
| Continuous | 3 ton/hour | 55 - 60 |
| Continuous reduction | 4-5 ton/hour | 140 - 165 |

Batch plant operating costs: $53/ton - $106/ton, depending on equipment size and raw material.

Continuous plant operating costs: $20/ton with output of 1 ton/hour.

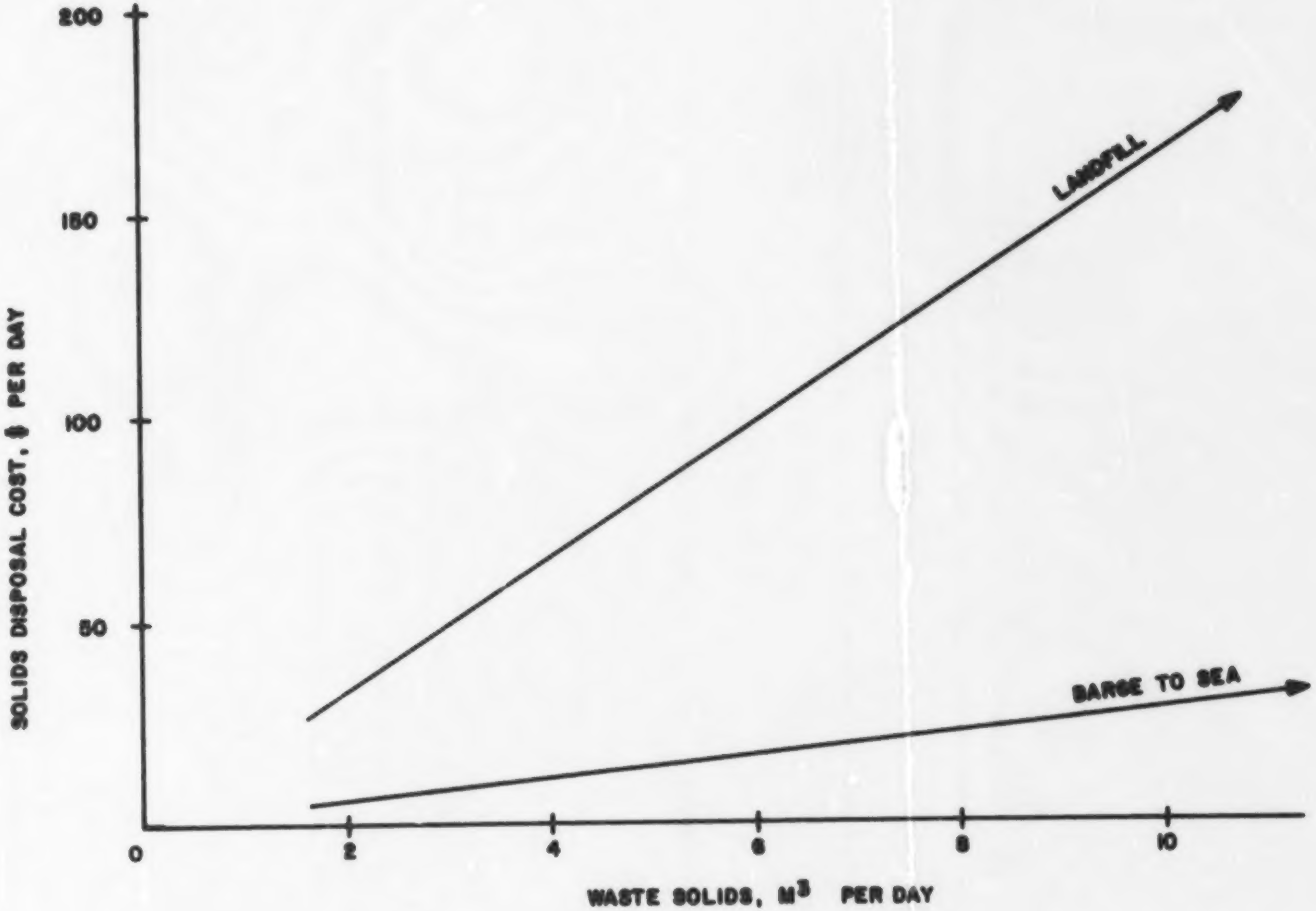


Figure 102. Waste disposal costs for landfill or ocean disposal.

## SECTION IX

## BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE, GUIDELINES AND LIMITATIONS

For each subcategory within the canned and preserved fish and seafood processing industry, the "best practicable control technology currently available" (BPCTCA) must be achieved by all plants not later than July 1, 1977. BPCTCA, except for the fish meal production industry, is not based on "the average of the best existing performance by plants of various sizes, ages and unit processes within each . . . subcategory," but, rather, represents the highest level of control that can be practicably applied by July 1, 1977 because present control and treatment practices are generally inadequate within the finfish and shellfish segments of the canned and preserved fish and seafood processing industry. BPCTCA for the fish meal process with solubles plant was determined using an average of the exemplary plants. Consideration of the following factors has been included in the establishment of BPCTCA:

1) the total cost of application of technology in relation to the effluent reduction benefits to be achieved from this application;

2) the age of the equipment and facilities involved;

3) the processes employed;

4) the engineering aspects of the application of various types of control techniques;

5) process changes; and

6) non-water quality environmental impact.

Furthermore, the designation of BPCTCA technology emphasized end-of-pipe treatment technology, but included in-process technology when considered normal practice within the subcategory.

An important consideration in the designation process was the degree of economic and engineering reliability required to determine the technology to be "currently available." In this industry, the reliability of the recommended technologies was established based on pilot plants, demonstration projects, and transfer technology, the latter mainly from the meat packing and municipal waste treatment fields.

Since few seafood processing wastewater treatment systems have been installed, there is no data base available to develop maximum 30-day averages and daily maxima for wastewater effluent levels after treatment. Therefore, engineering judgment based on the information and advice from the following sources was used to develop statistical models of the effluent and treatment systems: 1) engineering handbooks, 2) seafood processing and environmental engineering consultants, 3) industry contacts, 4) technical papers, 5) currently available data, and 6) data developed during this study. These models were then used to estimate the resulting effluent levels. Sections V and VII discuss the models which were used and presents the levels to which treatment removal factors were applied to determine the effuent levels which can be achieved using BPCTCA.

A subcategory listing of the effluent limitations along with the associated treatment technologies is presented in Table 200. Tables 150 and 151 (Section VII) present the expected removal efficiencies of the various technologies considered.

## In-Plant Housekeeping

No additional treatment is considered necessary for fish meal processes with solubles plants since the waste load concentrations are quite low and it would be very difficult and expensive to treat the effluent any further. However, waste load reductions can be attained through "good housekeeping" practices which are considered normal practice within the seafood processing industry such as turning off faucets and hoses when not in use or using spring-loaded hose nozzles.

## Barge to Sea or By-Product Recovery

Since there is no cost effective end-of-pipe treatment available for stickwater, it is recommended that fish meal processes with no existing solubles plant barge stickwater, recycled bailwater and washdown water to sea or, preferably to another fish meal operation with solubles plant for by-product recovery. The only remaining wastewater would be from an air scrubber or leaks from the unit operations.

## Direct Discharge of Comminuted Solids

There is substantial evidence that processors in isolated and remote areas of Alaska are at a comparative economic disadvantage to the processors located in population or processing centers regarding attempts to meet the effluent limitations. The isolated location of some Alaskan seafood processing plants eliminates almost all waste water treatment alternatives because of undependable access to ocean, land, or commercial transportation disposal methods during extended severe sea or weather conditions, and the high costs of eliminating the engineering obstacles due to adverse climatic and geologic conditions. However, those plants located in population or processing centers have access to more reliable, cost-effective alternatives such as solids recovery techniques or other forms of solids disposal such as landfill or barging.

BPCTCA for isolated Alaskan seafood processors constitutes direct discharge of comminuted solids.

## In-Plant Housekeeping and Screen

In-plant housekeeping and screening are considered BPCTCA technology for the non-oily species and for the Alaska commodities processed in population or processing centers. Air flotation is estimated to remove only 30 percent of the BOD without chemical optimization and 50 percent with chemical optimization for non-oily commodities and is not considered to be cost effective. Air flotation is technically practicable for salmon canning; however, the high shipping and construction costs in Alaska make this technology economically impractical in this region for BPCTCA.

## In-plant housekeeping, screen and air flotation

In addition to good housekeeping practices, screens and air flotation are considered BPCTCA for the oily species outside of Alaska. These include Northwest salmon canning where mechanical butchering is used mechanized bottom fish, herring filleting, and sardine canning. However, because of the economic impact of the cost of such treatment the effluent limitations for mechanized bottom fish and herring filleting are based on good hosuekeeping practices and screening. The effluent limitations for the sardine processors are based on treatment by screening and simple grease traps for the precook water (about 5 percent of plant flow) and treatment by screening only for the remainder of the flow. The precook water contains approximately 70 percent of the total grease and oil for plants with essentially dry transport systems to the packing tables.

The effluent limitations for each subcategory are presented in Table 200. These values, except for fish meal, were obtained from the formulas presented in Figure 94. The percent removal factors are listed in Tables 150 and 151. Fish meal with solubles plant limitations are based on current practice which required no further end-of-pipe treatment. Fish meal without solubles plant limitations were based on air scrubber water and wash water which remains after the stickwater and bailwater has been barged to sea.

## TABLE 200
## JULY 1, 1977 EFFLUENT LIMITATIONS

Parameter (kg/kkg or lbs/1000 lbs seafood processed)

| Subcategory | Technology (BPCTCA) | BOD5 Daily Max | BOD5 Max 30-Day avg | TSS Daily Max | TSS Max 30-Day avg | Grease & Oil Daily Max | Grease & Oil Max 30-Day avg |
|---|---|---|---|---|---|---|---|
| O. Fish Meal | | | | | | | |
| 1. with solubles unit | H | 4.7 | 3.5 | 2.3 | 1.3 | 0.80 | 0.63 |
| 2. w/o solubles unit | B | 3.5 | 2.8 | 2.6 | 1.7 | 3.2 | 1.4 |
| P. AK hand-butchered salmon | | | | | | | |
| 1. non-remote | H,S,B | - | - | 1.7 | 1.4 | 0.20 | 0.17 |
| 2. remote | Grind | * | * | * | * | * | * |
| Q. AK mechanized salmon | | | | | | | |
| 1. non-remote | H,S,B | - | - | 27 | 22 | 27 | 10 |
| 2. remote | Grind | * | * | * | * | * | * |
| R. West Coast hand-butchered salmon | H,S | - | - | 1.7 | 1.4 | 0.20 | 0.17 |
| S. West Coast mechanized salmon | H,S | - | - | 27 | 22 | 27 | 10 |
| T. AK bottom fish | | | | | | | |
| 1. non-remote | H,S,B | - | - | 3.0 | 1.9 | 4.3 | 0.56 |
| 2. remote | Grind | * | * | * | * | * | * |
| U. Non-AK conventional bottom fish | H,S | - | - | 2.1 | 1.6 | 0.55 | 0.40 |
| V. Non-AK mechanized bottom fish | H,S | - | - | 14 | 10 | 5.7 | 3.3 |
| W. Hand-shucked clams | H,S | - | - | 59 | 18 | 0.60 | 0.23 |

Table 200(cont'd) July 1, 1977 Effluent Limitations

| Subcategory | Technology (BPCTCA) | Parameter (kg/kkg or lbs/1000 lbs seafood processed) BOD5 | | TSS | | Grease & Oil | |
|---|---|---|---|---|---|---|---|
| | | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg |
| X. Mechanized clams | H,S | - | - | 90 | 15 | 4.2 | 0.97 |
| Y. Pacific Coast hand-shucked oysters** | H,S | - | - | 37 | 35 | 1.7 | 1.6 |
| Z. East & Gulf Coast hand-shucked oysters** | H,S | - | - | 19 | 15 | 0.77 | 0.70 |
| AA. Steamed/Canned oysters** | H,S | - | - | 270 | 190 | 2.3 | 1.7 |
| AB. Sardines | | | | | | | |
| 1. dry conveying | H,S,GT*** | - | - | 36 | 10 | 3.5 | 1.4 |
| 2. wet flume | H,S,GT*** | - | - | 48 | 16 | 6.3 | 2.8 |
| AC. AK scallops** | | | | | | | |
| 1. non-remote | H,S,B | - | - | 6.0 | 1.4 | 7.7 | 0.24 |
| 2. remote | Grind | * | * | * | * | - | * |
| AD. Non-AK scallops** | H,S | - | - | 6.0 | 1.4 | 7.7 | 0.24 |
| AE. AK herring fillet | | | | | | | |
| 1. non-remote | H,S,B | - | - | 32 | 24 | 27 | 10 |
| 2. remote | Grind | * | * | * | * | * | * |

Table 200 (cont'd) July 1, 1977 Effluent Limitations

| | | Parameter (kg/kkg or lbs/1000 lbs seafood processed) | | | | | |
|---|---|---|---|---|---|---|---|
| | | BOD5 | | TSS | | Grease & Oil | |
| Subcategory | Technology (BPCTCA) | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg |
| AF. Non-AK herring fillet | H,S | - | - | 32 | 24 | 27 | 10 |
| AG. Abalone | H,S | - | - | 27 | 15 | 2.2 | 1.4 |

H = housekeeping; S = screen; DAF = dissolved air flotation without chemical optimization;
B = barge solids; GT = grease trap

*No pollutants may be discharged which exceed 1.27 cm (0.5 inch) in any dimension

**Effluent limitations in terms of finished product

***Effluent limitations are based on treatment of the pre-cook water by screening and skimming of free oil, and screening for the remainder of the effluent

# SECTION X

## BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE, GUIDELINES AND LIMITATIONS

For each subcategory within the canned and preserved fish and seafood processing industry, the "best available technology economically achievable" (BATEA) must be realized by all plants not later than July 1, 1983. BATEA is, for this industry, not the very best control and treatment technology employed by a specific point source within the industrial category or subcategory, but represents "transfer technology" especially from the meat packing industry, other segments of the seafood industry, and municipal waste treatment experience. This was necessary because present control and treatment practices except for the fish meal portion of the industry are generally inadequate.

Consideration of the following factors has been included in the establishment of the best available technology economically achievable:

1) equipment and facilities age;

2) processes employed;

3) engineering aspects of various control technique applications;

4) process changes;

5) costs of achieving the effluent reduction resulting from the application of BATEA technology; and

6) non-water quality environmental impact.

Furthermore, in-plant controls were emphasized in the designation of BATEA technology. Those in-process and end-of-pipe controls recommended for BATEA were subjected to the criterion that they be demonstrated at the pilot plant, semi-works, or other level to be technologically and economically justifiable. This is not to say that a complete economic analysis of each proposed system and its relationship to one or more subcategories has been undertaken. Rather, the information and advice from 1) engineering handbooks, 2) seafood processing and environmental engineering consultatns, 3) industry contacts, 4) technical papers, 5) currently available data, and 6) data developed during this study has been applied in the consideration of all alternatives and those with a reasonable chance of "viability" in application to a significant number of actual processing plants within a subcategory have been considered in detail.

It should be noted that the wastewater treatment technologies and in-plant changes which serve as the basis for the effluent limitations represent only one alternative open to the processor.

The BATEA effluent limitations, in terms of maximum 30-day averages and daily maxima were developed using the same statistical models as were used for BPCTCA and incorporating generally improved treatment and control efficiencies. Table 152 (Section VII) lists the estimated practicable in-plant waste water flow reductions and associated pollutional loadings reductions.

## In-Plant Changes

Modifying the fish meal plants to contain leaks from the unit operations, treating bailwater to reduce the load on the solubles plant, and modifying the evaporators such that they operate in a more continuous manner, should reduce the average BOD load by about 5 percent. Fish meal processes without a solubles plant can install an evaporator for BATEA or barge the effluent to another plant for byproduct recovery. The effluent limitations for all fish meal processes will therefore be the same for the 1983 standards.

## Housekeeping and Screen

The processes in the hand-shucked oyster subcategories are typically small in size and operate in an intermittent manner. Even though extended aeration was considered to be the least expensive technically feasible treatment alternative, the projected severe economic impact precluded such treatment. Therefore, the BATEA effluent limitation are based on good housekeeping practices and screening of the effluent prior to discharge to the receiving waters.

## In-Plant Changes and Screen

The processes in several subcategories are typically small in size, utilize non-oily species, and operate in an intermittent manner. Therefore, lagoons, air flotation and extended aeration were not considered economically or technically feasible in these cases. It was considered possible to reduce the water flow and waste loads through in-plant changes; a small amount for the shellfish processes and a greater amount for the salmon and bottom fish.

## In-Plant Changes, Screen and Air Flotation

Air flotation together with in-plant changes was considered equivalent to biological treatment for the salmon canning and herring processing industries for BATEA.

In-plant changes for the non-Alaska herring and salmon processes increased the overall BOD removals from 2 percent to 15 percent. The larger removals shown for the sardine process assumed that the precook water from the sardine plants would be handled separately. Air flotation is also recommended for the mechanized bottom fish process which was observed to be higher in grease and oil content than the conventional processes.

## In-Plant Changes, Screen and Aerated Lagoon

An aerated lagoon was considered to be the only advanced treatment available which could be applied to subcategories processing non-oily species, have relatively low BOD concentrations, and relatively large flows. This included the hand butchered salmon processes, the non-Alaska conventional bottom fish processes, the mechanized clam processes, and the steamed or canned oyster processes. In-plant changes increased the BOD removal up to an additional 5 percent.

## Effluent Limitations

The July 1, 1983, effluent limitations for each subcategory are presented in Table 201. These values were obtained by applying the removal factors (Tables 150, 151, and 152) of the control and treatment technologies to the raw effluent daily maxima and maximum 30 day averages presented in Section V. Except for fish meal, these valves were obtained by the formulas presented in Figure 94. The fish meal limitations are based on the operation of a by-product recovery solubles unit operation.

Table 201
July 1, 1983 Effluent Limitations

| Subcategory | Technology (BATEA) | Parameter (kg/kkg or lbs/1000 lbs seafood processed) BOD5 Daily Max. | BOD5 Max. 30-Day avg. | TSS Daily Max. | TSS Max. 30-Day avg. | Grease & Oil Daily Max. | Grease & Oil Max. 30-Day avg. |
|---|---|---|---|---|---|---|---|
| O. Fish meal | IP | 4.0 | 2.6 | 2.3 | 1.3 | 0.80 | 0.63 |
| P. Ak hand-butchered salmon | IP,S,B | - | - | 1.5 | 1.2 | 0.18 | 0.15 |
| Q. Ak mechanized salmon | | | | | | | |
| 1. non-remote | IP,S,DAF,B | 16 | 13 | 2.6 | 2.2 | 2.6 | 1.0 |
| 2. remote | IP,S,B | - | - | 26 | 21 | 26 | 10 |
| R. West Coast hand-butchered salmon | IP,S,DAF | 1.2 | 1.0 | 0.15 | 0.12 | 0.045 | 0.018 |
| S. West Coast mechanized salmon | IP,S,DAF | 16 | 13 | 2.6 | 2.2 | 2.6 | 1.0 |
| T. Ak bottom fish | IP,S,B | - | - | 1.9 | 1.1 | 2.6 | 0.34 |
| U. Non-Ak conventional bottom fish | IP,S,AL | 0.73 | 0.58 | 1.5 | 0.73 | 0.04 | 0.03 |
| V. Non-Ak mechanized bottom fish | IP,S,DAF | 6.5 | 5.3 | 1.1 | 0.82 | 0.46 | 0.26 |
| W. Hand-shucked clams | IP,S | - | - | 55 | 17 | 0.56 | 0.21 |
| X. Mechanized clams | IP,S,AL | 15 | 5.7 | 26 | 4.4 | 0.40 | 0.092 |

Table 201 (Cont'd)
Proposed July 1, 1983 Effluent Limitations

| Subcategory | Technology (BATEA) | Parameter BOD5 | | (kg/kkg or lbs/1000 lbs seafood processed) TSS | | Grease & Oil | |
|---|---|---|---|---|---|---|---|
| | | Daily Max. | Max. 30-Day avg. | Daily Max. | Max. 30-Day avg. | Daily Max. | Max. 30-Day avg. |
| Y. Pacific Coast hand-shucked oysters* | H,S | - | - | 37 | 35 | 1.7 | 1.6 |
| Z. East Gulf Coast hand-shucked oysters* | H,S | - | - | 19 | 15 | 0.77 | 0.70 |
| AA. Steamed/Canned oysters* | IP,S,AL | 67 | 17 | 56 | 39 | 0.84 | 0.42 |
| AB. Sardines | IP,S,DAF** | - | - | 36 | 10 | 1.3 | 0.52 |
| AC. Ak scallops* | IP,S,B | - | - | 5.7 | 1.4 | 7.3 | 0.23 |
| AD. Non-Ak scallops* | IP,S | - | - | 5.7 | 1.4 | 7.3 | 0.23 |
| AE. Ak herring fillets | | | | | | | |
| 1. non-remote | IP,S,DAF,B | 6.8 | 6.2 | 2.3 | 1.8 | 2.0 | 0.73 |
| 2. remote | IP,S,B | - | - | 23 | 18 | 20 | 7.3 |

Table 201 (Cont'd)
Proposed July 1, 1983 Effluent Limitations

| Subcategory | Technology (BATEA) | Parameter BOD5 | | TSS | | Grease & Oil (kg/kkg or lbs/1000 lbs seafood processed) | |
|---|---|---|---|---|---|---|---|
| | | Daily Max. | Max. 30-Day avg. | Daily Max. | Max. 30-Day avg. | Daily Max. | Max. 30-Day avg. |
| AF. Non-Ak herring fillets | IP,S,DAF | 6.8 | 6.2 | 2.3 | 1.8 | 2.0 | 0.73 |
| AG. Abalone | IP,S | - | - | 26 | 14 | 2.1 | 1.3 |

IP = in-plant process changes; S = screen; DAF = dissolved air flotation with chemical optimization;
AL = aerated lagoon; EA = extended aeration; B = barge solids

*Effluent Limitations in terms of finished product

**Effluent limitations based on DAF treatment of the can wash and pre-cook water, and screening for the remainder of the effluent

# SECTION XI

## NEW SOURCE PERFORMANCE STANDARDS AND PRETREATMENT STANDARDS

The effluent limitations that must be achieved by new sources are termed "Performance Standards." The New Source Performance Standards apply to any source for which construction starts after the promulgation of the regulations for the standards. The standards were determined by adding to the consideration underlying the identification of the "Best Practicable Control Technology Currently Available" a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques. Thus, in addition to considering the best in-plant and end-of-process control technology, New Source Performance Standards are based on an analysis of how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods, or other alternatives were considered. A further determination made was whether a standard permitting no discharge of pollutants is practicable.

Consideration was also given to:

1) operating methods;
2) batch as opposed to continuous operations;
3) use of alternative raw materials and mixes of raw materials;
4) use of dry rather than wet processes (including a substitution of recoverable solvents for water); and
5) recovery of pollutants as by-products.

The effluent limitations for new sources are based on currently available technology with appropriate effluent level reductions due to in-plant modifications as discussed in Sections VII and X.

### Effluent Limitation for New Source Performance Standards

The effluent limitations and associated technology for each subcategory are presented in Table 202. These values were obtained in the same manner as described for BPCTCA and BATEA in Sections IX and X.

## Pretreatment Requirements

No constituents of the effluents discharged from plants within the segments of the seafood industry included in this study have been found which would (in concentrations found in the effluent) interfere with, pass through (to the detriment of the environment) or otherwise be incompatible with a well-designed and operated publicly owned activated sludge or trickling filter wastewater treatment plant. The effluent, however, should have passed through (primary treatment) in the plant to remove settleable solids and a large portion of the greases and oils. Furthermore, in a few cases, it should have been mixed with sufficient wastewater flows from other sources to dilute out the inhibitory effect of any sodium chloride concentrations which may have been released from the seafood processing plant. The concentration of pollutants acceptible to the treatment plant is dependent on the relative sizes of the treatment facility and the processing plant and must be established by the treatment facility.

## TABLE 202
## NEW SOURCE PERFORMANCE STANDARDS

Parameter (kg/kkg or lbs/1000 lbs seafood processed)

| Subcategory | Technology | BOD5 Daily Max | BOD5 Max 30-Day avg | TSS Daily Max | TSS Max 30-Day avg | Grease & Oil Daily Max | Grease & Oil Max 30-Day avg |
|---|---|---|---|---|---|---|---|
| O. Fish meal | IP | 4.0 | 2.9 | 2.3 | 1.3 | 0.80 | 0.63 |
| P. Ak hand-butchered salmon | | | | | | | |
| 1. non-remote | IP,S,B | - | - | 1.5 | 1.2 | 0.18 | 0.15 |
| 2. remote | grind | * | * | * | * | * | * |
| Q. Ak mechanized salmon | | | | | | | |
| 1. non-remote | IP,S,B, | - | - | 26 | 21 | 26 | 10 |
| 2. remote | grind | * | * | * | * | * | * |
| R. West Coast hand-butchered salmon | IP,S,DAF | 1.7 | 1.4 | 0.46 | 0.37 | 0.058 | 0.023 |
| S. West Coast mechanized salmon | IP,S,DAF | 36 | 32 | 7.9 | 6.5 | 3.8 | 1.5 |
| T. Ak bottom fish | | | | | | | |
| 1. non-remote | IP,S,B | - | - | 1.9 | 1.1 | 2.6 | 0.34 |
| 2. remote | grind | * | * | * | * | * | * |
| U. Non-Ak conventional bottom fish | IP,S,AL | 0.73 | 0.58 | 1.5 | 0.73 | 0.04 | 0.03 |
| V. Non-Ak mechanized bottom fish | IP,S,DAF | 9.1 | 7.4 | 3.3 | 2.5 | 0.68 | 0.39 |
| W. Hand-shucked clams | IP,S | - | - | 55 | 17 | 0.56 | 0.21 |

Table 202 (Cont'd) New Source Performance Standards

| | | Parameter | (kg/kkg or lbs/1000 lbs seafood processed) | | | | |
|---|---|---|---|---|---|---|---|
| | | BOD5 | | TSS | | Grease & Oil | |
| Subcategory | Technology | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg |
| X. Mechanized clams | IP,S,AL | 15 | 5.7 | 26 | 4.4 | 0.40 | 0.092 |
| Y. Pacific Cost hand-shucked oysters** | H,S | - | - | 37 | 35 | 1.7 | 1.6 |
| Z. East & Gulf Coast hand-shucked oysters** | H,S | - | - | 19 | 15 | 0.77 | 0.70 |
| AA. Steamed/Canned oysters** | IP,S,AL | 67 | 17 | 56 | 39 | 0.84 | 0.42 |
| AB. Sardines | IP,S,DAF*** | - | - | 36 | 10 | 1.4 | 0.57 |
| AC. Ak scallops** | | | | | | | |
| 1. non-remote | IP,S,B | - | - | 5.7 | 1.4 | 7.3 | 0.23 |
| 2. remote | grind | * | * | * | * | * | * |
| AD. Non-Ak scallops | IP,S | - | - | 5.7 | 1.4 | 7.3 | 0.23 |
| AE. Ak herring fillIets | | | | | | | |
| 1. non-remote | IP,S,B | - | - | 23 | 18 | 20 | 7.3 |
| 2. remote | grind | * | * | * | * | * | * |

Table 202 (Cont'd) New Source Performance Standards

Parameter (kg/kkg or lbs/1000 lbs seafood processed)

| Subcategory | Technology | BOD5 | | TSS | | Grease & Oil | |
|---|---|---|---|---|---|---|---|
| | | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg | Daily Max | Max 30-Day avg |
| AF. Non-Ak herring fillets | IP,S,DAF | 16 | 15 | 7.0 | 5.2 | 2.9 | 1.1 |
| AG. Abalone | IP,S | - | - | 26 | 14 | 2.1 | 1.3 |

IP = in-plant process changes; S = screen; DAF = dissolved air flotation without chemical optimization; AL = aerated lagoon; EA = extended aeration; B = barge solids

*No pollutants may be discharged which exceed 1.27 cm (0.5 inch) in any dimension

**Effluent limitations in terms of finished product

***Effluent limitations based on DAF treatment of the can wash and pre-cook water, and screening for the remainder of the effluent

## SECTION XII

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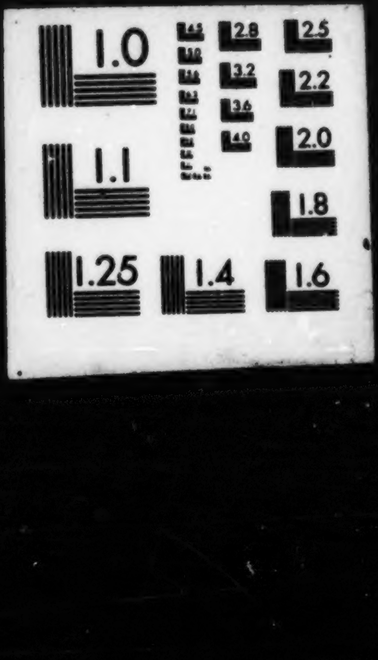
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# SECTION XIV

## GLOSSARY

**Activated Sludge Process:** Removes organic matter from wastewater by saturating it with air and biologically active sludge.

**Aeration Tank:** A chamber for injecting air or oxygen into water.

**Aerobic Organism:** An organism that thrives in the presence of oxygen.

**Algae (Alga):** Simple plants, many microscopic, containing chlorophyll. Most algae are aquatic and may produce a nuisance when conditions are suitable for prolific growth.

**Algorithm:** Any mechanical or repetitive computational procedure.

**Ammonia Stripping:** Ammonia removal from a liquid, usually by intimate contact with an ammonia-free gas, such as air.

**Anadromous:** Type of fish that ascend rivers from the sea to spawn.

**Anaerobic:** Living or active in the absence of free oxygen.

**Aquaculture:** The cultivation and harvesting of aquatic plants and animals.

**Bacteria:** The smallest living organisms which comprise, along with fungi, the decomposer category of the food chain.

**Bailwater:** Water used to facilitate unloading of fish from fishing vessel holds.

**Barometric Leg:** Use of moving streams of water to draw a vacuum; aspirator.

**Batch Cooker:** Product remains stationary in cooker (water is periodically changed).

**Benthic Region:** The bottom of a body of water. This region supports the benthos, a type of life that not only lives upon but contributes to the character of the bottom.

**Benthos:** Aquatic bottom-dwelling organisms. These include: (1) Sessile Animals, such as the sponges, barnacles, mussels, oysters, some of the worms, and many attached algae; (2) creeping forms, such as insects, snails and certain clams; and (3) burrowing forms, which include most clams and worms.

**Bight:** An indentation or recess in the shore of a sea; a bay.

Biological Oxidation: The process whereby, through the activity of living organisms in an aerobic environment, organic matter is converted to more biologically stable matter.

Biological Stabilization: Reduction in the net energy level or organic matter as a result of the metabolic activity of organisms, so that further biodegradation is very slow.

Biological Treatment: Organic waste treatment in which bacteria and/or biochemical action are intensified under controlled conditions.

Blow Tank: Water-filled tank used to wash oyster or clam meats by agitating with air injected at the bottom.

BOD (Biochemical Oxygen Demand): Amount of oxygen necessary in the water for bacteria to consume the organic sewage. It is used as a measure in telling how well a sewage treatment plant is working.

BOD-5: A measure of the oxygen consumption by aerobic organisms over a 5-day test period at 20°C. It is an indirect measure of the concentration of biologically degradable material present in organic wastes contained in a waste stream.

Botulinus Organisms: Those that cause acute food poisoning.

Breading: A finely ground mixture containing cereal products, flavorings and other ingredients, that is applied to a product that has been moistened, usually with batter.

Brine: Concentrated salt solution which is used to cool or freeze fish.

BTU: British thermal unit, the quantity of heat required to raise one pound of water 1°F.

Building Drain: Lowest horizontal part of a building drainage system. Building Drainage System: Piping provided for carrying wastewater or other drainage from a building to the street sewer.

Bulking Sludge: Activated sludge that settles poorly because of low-density floc.

Canned Fishery Product: Fish, shellfish, or other aquatic animals packed singly or in combination with other items in hermetically sealed, heat sterilized cans, jars, or other suitable containers. Most, but not all, canned fishery products can be stored at room temperature for an indefinite period of time without spoiling.

Carbon Adsorption: The separation of small waste particles and molecular species, including color and odor contaminants, by attachment to the surface and open pore structure of carbon granules or powder. The carbon is "activated," or made more adsorbent by treatment and processing.

Case: "Standard" packaging in corrugated fiberboard containers.

Centrifugal Decanter: A device which subjects material in a steady stream to a centrifugal force and continuously discharges the separated components.

COD (Chemical Oxygen Demand): A measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water.

Chemical Precipitation: A waste treatment process whereby substances dissolved in the wastewater stream are rendered insoluble and form a solid phase that settles out or can be removed by flotation techniques.

Clarification: Process of removing undissolved materials from a liquid. Specifically, removal of solids either by settling or filtration.

Clarifier: A settling basin for separating settleable solids from wastewater.

Coagulant: A material, which, when added to liquid wastes or water, creates a reaction which forms insoluble floc particles that adsorb and precipitate colloidal and suspended solids. The floc particles can be removed by sedimentation. Among the most common chemical coagulants used in sewage treatment are ferric chloride, alum and lime.

Coagulation: The clumping together of solids to make them settle out of the sewage faster. Coagulation of solids is brought about with the use of certain chemicals such as lime, alum, or polyelectrolytes.

Coefficient of Variation: A measure used in describing the amount of variation in a population. An estimate of this value is S/X where "S" equals the standard deviation and X equals the sample mean.

Coelom: The body cavity of a specific group of animals in which the viscera is located.

Coliform: Relating to, resembling, or being the colon bacillus.

Comminutor: A device for the catching and shredding of heavy solid matter in the primary stage of waste treatment.

Concentration: The total mass (usually in micrograms) of the suspended particles contained in a unit volume (usually one cubic meter) at a given temperature and pressure; sometimes, the concentration may be expressed in terms of total number of particles in a unit volume (e.g., parts per million); concentration may also be called the "loading" or the "level" of a substance; concentration may also pertain to the strength of a solution.

**Condensate**: Liquid residue resulting from the cooling of a gaseous vapor.

**Contamination**: A general term signifying the introduction into water of microorganisms, chemical, organic, or inorganic wastes, or sewage, which renders the water unfit for its intended use.

**Correlation Coefficient**: A measure of the degree of closeness of the linear relationship between two variables. It is a pure number without units or dimensions, and always lies between -1 and +1.

**Crustacea**: Mostly aquatic animals with rigid outer coverings, jointed appendages, and gills. Examples are crayfish, crabs, barnacles, water fleas, and sow bugs.

**Cultural Eutrophication**: Acceleration by man of the natural aging process of bodies of water.

**Cyclone**: A device used to separate dust or mist from gas stream by centrifugal force.

**Decomposition**: Reduction of the net energy level and change in chemical composition of organic matter because of actions of aerobic or anaerobic microorganisms.

**Denitrification**: The process involving the facultative conversion by anaerobic bacteria of nitrates into nitrogen and nitrogen oxides.

**Deviation, Standard Normal**: A measure of dispersion of values about a mean value; the square root of the average of the squares of the individual deviations from the mean.

**Digestion**: Though "aerobic" digestion is used, the term digestion commonly refers to the anaerobic breakdown of organic matter in water solution or suspension into simpler or more biologically stable compounds or both. Organic matter may be decomposed to soluble organic acids or alcohols, and subsequently converted to such gases as methane and carbon dioxide. Complete destruction of organic solid materials by bacterial action alone is never accomplished.

**Dissolved Air Flotation**: A process involving the compression of air and liquid, mixing to super-saturation, and releasing the pressure to generate large numbers of minute air bubbles. As the bubbles rise to the surface of the water, they carry with them small particles that they contact.

**Dissolved Oxygen (D.O.)**: Due to the diurnal fluctuations of dissolved oxygen in streams, the minimum dissolved oxygen value shall apply at or near the time of the average concentration in the stream, taking into account the diurnal fluctuations.

**Echinodermata**: The phylum of marine animals characterized by an unsegmented body and secondary radial symmetry, e.g., sea stars, sea urchins, sea cucumbers, sea lilies.

**Ecology**: The science of the interrelationship between living organisms and their environment.

**Effluent**: Something that flows out, such as a liquid discharged as a waste; for example, the liquid that comes out of a treatment plant after completion of the treatment process.

**Electrodialysis**: A process by which electricity attracts or draws the mineral salts from sewage.

**Enrichment**: The addition of nitrogen, phosphorus, carbon compounds and other nutrients into a waterway that increases the growth potential for algae and other aquatic plants. Most frequently, enrichment results from the inflow sewage effluent or from agricultural runoff.

**Environment**: The physical environment of the world consisting of the atmosphere, the hydrosphere, and the lithosphere. The biosphere is that part of the environment supporting life and which is important to man.

**Estuary**: Commonly an arm of the sea at the lower end of a river. Estuaries are often enclosed by land except at channel entrance points.

**Eutrophication**: The normally slow aging process of a body of water as it evolves eventually into a terrestrial state as effected by the enrichment of the water.

**Eutrophic Waters**: Waters with a good supply of nutrients. These waters may support rich organic productions, such as algal blooms.

**Extrapolate**: To project data into an area not known or experienced, and arrive at knowledge based on inferences of continuity of the data.

**Facultative Aerobe**: An organism that although fundamentally an anaerobe can grow in the presence of free oxygen.

**Facultative Anaerobe**: An organism that although fundamentally an aerobe can grow in the absence of free oxygen.

**Facultative Decomposition**: Decomposition of organic matter by facultative microorganisms.

Fish Fillets: The sides of fish that are either skinned or have the skin on, cut lengthwise from the backbone. Most types of fillets are boneless or virtually boneless; some may be specified as "boneless fillets."

Fish Meal: A ground, dried product made from fish or shellfish or parts thereof, generally produced by cooking raw fish or shellfish with steam and pressing the material to obtain the solids which are then dried.

Fish Oil: An oil processed from the body (body oil) or liver (liver oil) of fish. Most fish oils are a by-product of the production of fish meal.

Fish Solubles: A product extracted from the residual press liquor (called "stickwater") after the solids are removed for drying (fish meal) and the oil extracted by centrifuging. This residue is generally condensed to 50 percent solids and marketed as "condensed fish solubles."

Filtration: The process of passing a liquid through a porous medium for the removal of suspended material by a physical straining action.

Floc: Something occurring in indefinite masses or aggregates. A clump of solids formed in sewage when certain chemicals are added.

Flocculation: The process by which certain chemicals form clumps of solids in sewage.

Floc Skimmings: The flocculent mass formed on a quiescent liquid surface and removed for use, treatment, or disposal.

Flume: An artificial channel for conveyance of a stream of water.

Grab Sample: A sample taken at a random place in space and time.

Groundwater: The supply of freshwater under the earth's surface in an aquifier or soil that forms the natural reservoir for man's use.

Heterotrophic Organism: Organisms that are dependent on organic matter for food.

Identify: To determine the exact chemical nature of a hazardous polluting substance.

Impact: (1) An impact is a single collision of one mass in motion with a second mass which may be either in motion or at rest. (2) Impact is a word used to express the extent or severity of an environmental problem; e.g., the number of persons exposed to a given noise environment. Incineration: Burning the sludge to remove the water and reduce the remaining residues to a safe, non-burnable ash. The ash can then be disposed of safely on land, in some waters, or into caves or other underground locations.

Influent: A liquid which flows into a containing space or process unit.

Ion Exchange: A reversible chemical reaction between a solid and a liquid by means of which ions may be interchanged between the two. It is in common use in water softening and water deionizing.

Kg: Kilogram or 1000 grams, metric unit of weight.

Kjeldahl Nitrogen: A measure of the total amount of nitrogen in the ammonia and organic forms.

KWH: Kilowatt-hours, a measure of total electrical energy consumption.

Lagoons: Scientifically constructed ponds in which sunlight, algae, and oxygen interact to restore water to a quality equal to effluent from a secondary treatment plant.

Landings, Commercial: Quantities of fish, shellfish and other aquatic plants and animals brought ashore and sold. Landings of fish may be in terms of round (live) weight or dressed weight. Landings of crustaceans are generally on a live weight basis except for shrimp which may be on a heads-on or heads-off basis. Mollusks are generally landed with the shell on but in some cases only the meats are landed (such as scallops).

Live Tank: Metal, wood, or plastic tank with circulating seawater for the purpose of keeping a fish or shellfish alive until processed.

M: Meter, metric unit of length.

Mm: Millimeter = 0.001 meter.

Mg/l: Milligrams per liter; approximately equals parts per million; a term used to indicate concentration of materials in water.

MGD: Million gallons per day.

Mesenteries: The tissue lining the body cavities and from which the organs are suspended.

Microstrainer/microscreen: A mechanical filter consisting of a cylindrical surface of metal filter fabric with openings of 20-60 micrometers in size.

**Milt**: Reproductive organ (testes) of male fish.

**Mixed Liquor**: The name given the effluent that comes from the aeration tank after the sewage has been mixed with activated sludge and air.

**Municipal Treatment**: A city or community-owned waste treatment plant for municipal and, possibly, industrial waste treatment.

**Nitrate, Nitrite**: Chemical compounds that include the NO3- (nitrate) and NO2- (nitrite) ions. They are composed of nitrogen and oxygen, are nutrients for growth of algae and other plant life, and contribute to eutrophication.

**Nitrification**: The process of oxidizing ammonia by bacteria into nitrites and nitrates.

**Organic Content**: Synonymous with volatile solids except for small traces of some inorganic materials such as calcium carbonate which will lose weight at temperatures used in determining volatile solids.

**Organic Detritus**: The particulate remains of disintegrated plants and animals.

**Organic Matter**: The waste from homes or industry of plant or animal origin.

**Oxidation Pond**: A man-made lake or body of water in which wastes are consumed by bacteria. It is used most frequently with other waste treatment processes. An oxidation pond is basically the same as a sewage lagoon.

**Pelagic Region**: The open water environment of the ocean consisting of waters both over and beyond the continental shelf and which is inhabited by the free swimming fishes.

**Per Capita Consumption**: Consumption of edible fishery products in the United States, divided by the total civilian population.

**pH**: The pH value indicates the relative intensity of acidity or alkalinity of water, with the neutral point at 7.0. Values lower than 7.0 indicate the presence of acids; above 7.0 the presence of alkalies.

**Phylum**: A main category of taxonomic classification into which the plant and animal kingdoms are divided.

**Plankton (Plankter)**: Organisms of relatively small size, mostly microscopic, that have either relatively small powers of locomotion or that drift in that water with waves, currents, and other water motion.

**Polishing**: Final treatment stage before discharge of effluent to a water course, carried out in a shallow, aerobic lagoon or pond, mainly to remove fine suspended solids that settle very slowly. Some aerobic microbiological activity also occurs.

**Ponding**: A waste treatment technique involving the actual holdup of all wastewaters in a confined space with evaporation and percolation the primary mechanisms operating to dispose of the water.

**Pound/net**: A net laid perpendicularly out from the shoreline with a circular impoundment at the seaward end.

**ppm**: Parts per million, also referred to as milligrams per liter (mg/l). This is a unit for expressing the concentration of any substance by weight, usually as grams of substance per million grams of solution. Since a liter of water weighs one kilogram at a specific gravity of 1.0, one part per million is equivalent to one milligram per liter.

**Press cake**: In the wet reduction process for industrial fishes, the solid fraction which results when cooked fish (and fish wastes) are passed through the screw presses. **Press Liquor**: Stickwater resulting from the pressing of fish solids.

**Primary Treatment**: Removes the material that floats or will settle in sewage. It is accomplished by using screens to catch the floating objects and tanks for the heavy matter to settle in.

**Process Water**: All water that comes into direct contact with the raw materials, intermediate products, final products, by-products, or contaminated waters and air.

**Processed Fishery Product**: plants and animals, and products thereof, preserved by canning, freezing, cooking, dehydrating, drying, fermenting, pasteurizing, adding salt or other chemical substances, and other commercial processes. Also, changing the form of fish, shellfish or other aquatic plants and animals from their original state into a form in which they are not readily identifiable, such as fillets, steaks, or shrimp logs.

**Purse Seiner**: Fishing vessel utilizing a seine (net) that is drawn together at the bottom, forming a trap or purse.

**Receiving Waters**: Rivers, lakes, oceans, or other water courses that receive treated or untreated wastewaters.

**Recycle**: The return of a quantity of effluent from a specific unit or process to the feed stream of that same unit. This would also apply to return of treated plant wastewater for several plant uses.

**Regression:** A trend or shift toward a mean. A regression curve or line is thus one that best fits a particular set of data according to some principle.

**Retort:** Sterilization of a food product at greater than 248°F with steam under pressure.

**Re-use:** Water re-use, the subsequent use of water following an earlier use without restoring it to the original quality.

**Reverse Osmosis:** The physical separation of substances from a water stream by reversal of the normal osmotic process, i.e., high pressure, forcing water through a semi-permeable membrane to the pure water side leaving behind more concentrated waste streams. **Rotating Biological Contactor:** A waste treatment device involving closely spaced light-weight disks which are rotated through the wastewater allowing aerobic microflora to accumulate on each disk and thereby achieving a reduction in the waste content.

**Rotary Screen:** A revolving cylindrical screen for the separation of solids from a wastestream.

**Round (Live) Weight:** The weight of fish, shellfish or other aquatic plants and animals as taken from the water; the complete or full weight as caught.

**Sample, Composite:** A sample taken at a fixed location by adding together small samples taken frequently during a given period of time.

**Sand Filter:** Removes the organic wastes from sewage. The wastewater is trickled over a bed of sand. Air and bacteria decompose the wastes filtering through the sand. The clean water flows out through drains in the bottom of the bed. The sludge accumulating at the surface must be removed from the bed periodically.

**Sand Trap:** Basin in sewage line for collection of high density solids, specifically sand.

**Sanitary Sewers:** In a separate system, are pipes in a city that carry only domestic wastewater. The storm water runoff is taken care of by a separate system of pipes.

**Sanitary Landfill:** A site for solid waste disposal using techniques which prevent vector breeching, and controls air pollution nuisances, fire hazards and surface or groundwater pollution.

**Scatter Diagram:** A two dimensional plot used to visually demonstrate the relationship between two sets of data.

**Secondary Treatment:** The second step in most waste treatment systems in which bacteria consume the organic parts of the wastes. It is accomplished by bringing the sewage and bacteria together in trickling filters or in the activated sludge process.

Sedimentation Tanks: Help remove solids from sewage. The wastewater is pumped to the tanks where the solids settle to the bottom or float on top as scum. The scum is skimmed off the top, and solids on the bottom are pumped out to sludge digestion tanks.

Seine: Any of a number of various nets used to capture fish.

Separator: Separates the loosened shell from the shrimp meat.

Settleable Matter (Solids): Determined in the Imhoff cone test and will show the quantitative settling characteristics of the waste sample.

Settling Tank: Synonymous with "Sedimentation Tank."

Sewers: A system of pipes that collect and deliver wastewater to treatment plants or receiving streams.

Shaker Blower: Dries and sucks the shell off with a vacuum, leaving the shrimp meat.

Skimmer Table: A perforated stainless steel table used to dewater clams and oysters after washing.

Shock Load: A quantity of wastewater or pollutant that greatly exceeds the normal discharged into a treatment system, usually occurring over a limited period of time.

Sludge: The solid matter that settles to the bottom of sedimentation tanks and must be disposed of by digestion or other methods to complete waste treatment.

Slurry: A solids-water mixture, with sufficient water content to impart fluid handling characteristics to the mixture.

Sliming Table: Fish processing vernacular referring to the area in which fish are butchered and/or checked for completeness of butcher.

Spatial Average: The mean value of a set of observations distributed as a function of position.

Species (Both Singular and Plural): A natural population or group of populations that transmit specific characteristics from parent to offspring. They are reproductively isolated from other populations with which they might breed. Populations usually exhibit a loss of fertility when hybridizing.

Standard Deviation: A statistical measure of the spread or variation of individual measurements.

Steam Box: A form of cooker which precooks the product with the use of steam in order to remove oils and water from fish.

Stickwater: Water and entrained organics that originate from the draining or pressing of steam cooked fish products.

Stoichiometric Amount: The amount of a substance involved in a specific chemical reaction, either as a reactant or as a reaction product.

Stop Seine: A net placed across a stream or bay to catch or retain fish.

Stratification: A partition of the universe which is useful when the properties of sub-populations are of interest and used for increasing the precision of the total population estimation when stratum means are sufficiently different and the within stratum variances are appreciably smaller than the total population variance.

Sump: A depression or tank that serves as a drain or receptacle for liquids for salvage or disposal.

Suspended Solids: The wastes that will not sink or settle in sewage.

Surface Water: The waters of the United States including the territorial seas.

Synergism: A situation in which the combined action of two or more agents acting together is greater than the sum of the action of these agents separately.

Temporal Average: The mean value of a set of observations distributed as a function of time.

Tertiary Waste Treatment: Waste treatment systems used to treat secondary treatment effluent and typically using physicalchemical technologies to effect waste reduction. Synonymous with "Advanced Waste Treatment."

Troll Dressed: Refers to salmon which have been eviscerated at sea.

Total Dissolved Solids (TDS): The solids content of wastewater that is soluble and is measured as total solids content minus the suspended solids.

Trickling Filter: A bed of rocks or stones. The sewage is trickled over the bed so the bacteria can break down the organic wastes. The bacteria collect on the stones through repeated use of the filter.

Viscera: The internal organs of the body, especially those of the abdominal and thoracic cavities.

Viscus (pl. Viscera):

Water Quality Criteria: The levels of pollutants that affect the suitability of water for a given use. Generally, water use classification includes: public water supply; recreation; propagation of fish and other aquatic life; agricultural use and industrial use.

Weir: A fence, net, or waffle placed across a stream or bay to catch or retain fish. In engineering use it is a dam over which, or through a notch in which, the liquid carried by a horizontal open channel is constrained to flow.

Zero Discharge: The discharge of no pollutants in the wastewater stream of a plant that is discharging into a receiving body of water.

# Appendix A
# Selected Bibliography

## Air Flotation Use Within the Seafood Industry

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4. Claggett, F. G., and Wong, J., Salmon Canning Wastewater Clarification, Part II. Vancouver: Fisheries Research Board of Canada, Laboratory, February 1969.

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13. Peterson, P.L. Treatment of Shellfish Processing Wastewater by Dissolved Air Flotation. Unpublished report. Seattle: National Marine Fisheries Service, U.S.D.C. 1973

14. Snider, Irvin F. "Application of Dissolved Air Flotation in the Seafood Industry." Proceedings of the 17th Annual Atlantic Fisheries Technology Conference (AFTC). Annapolis, Maryland, 1972.

15. Kato, K., Ishikawa, S. "Fish Oil and Protein Recovered From Fish Processing Effluent" S. Wat. Sewage Wks. 1969.
"At a fish processing plant in Shimonoseki City, Japan, two flow lines (for horse mackerel, scabbard fish, and yellow croaker) produce waste waters amounting to 1800 tons daily from which purified oil and protein are recovered. Oil, first separated by gravitational flotation, passes through a heater and is then purified by two centrifugal operations. Underflow from the oil separator is coagulated and transferred to pressure flotation tanks to separate proteins which are finally dewatered by vacuum filtration. Data on the characteristics of the effluent, results of tests, and design specifications are described fully. The process removes about 86 percent of the suspended solids and about 77 percent of the BOD." ("Water Pollution Abstracts" 1970, (43), Abstract No. 787, London: Her Majesty's Stationery Office).

16. Vuuren, L.R.J., Stander, G.J., Henzen, M.R., Blerk, S.H.V., Hamman, P.F. "Dispersed Air Flocculation/Flotation for Stripping of Organic Pollutants from Effluent" Wat. Res. 1968.
"The principles of the dispersed air flotation system which is widely used in industry are discussed. A laboratory scale unit was developed to provide a compact portable system for use in field investigations, and tabulated results are given of its use in the treatment of sewage-works effluents and waste waters from fish factories, pulp and paper mills, and abattoirs showing that their polluting load was greatly reduced." ("Water Pollution Abstracts, 1968 (41)).

17. E.S. Hopkins, Einarsson, J. "Water Supply and Waste Disposal At a Food Processing Plant. J. Industrial Water and Wastes. 1961
"The water supply system and waste treatment facilities serving the Coldwater Seafood Corporation plant at Nanticoke, Md., are described. Waste waters from washing equipment and floors, containing fish oil, grease and dough pass to a grease flotation tank, equipped with an "Aer-o-Mix" aeration unit. The advantages of the facilities are discussed." ("Water Pollution Abstracts," 1961 (34), London: Her Majesty's Stationery Office).

18. Shifrin, S.M. et al., "Mechanical Cleaning of Waste Waters From Fish Canneries" Chemical Abstracts 76 1972

"Shifrin et al presented the results of studies on fish cannery waste treatment in the U.S.S.R. using impeller-type flotators. With a waste containing 603 mg/l of fats, 603 mg/l of ss, and 2,560 mg/l of COD, mechanical flotation reduced these values by 99.8, 86.5 and 59.8 percent, respectively. The flotators were claimed to be more effective than settlers operating with or without aeration. ("Journal Water Pollution Control Federation," 1973, (45), No. 6, p. 1117.)

# Appendix B

## Selected Bibliography

### Air Flotation Use Within the Meat and Poultry Industry

1. Wilkinson, B.H..P. "Acid coagulation and dissolved air flotation." Proc. 13th Meat Ind. Res. Conf., Hamilton, N.Z., 1971, M.I.R.I.N.Z. No. 225,

"A process developed by the Meat Industry Research Institute of New Zealand for removal of colloidal proteins from meat trade waste waters comprises cogulation with acid followed by air flotation. Pilot-plant trials have achieved removals of 85-95 percent suspended solids, 70-80 percent BOD and COD, and 99 percent coliform organisms." ("Water Pollution Abstracts" 1972, (45), Abstract No. 478, London: Her Majesty's Stationery Office).

2. Woodard, F.E., Sproul, O.J., Hall, M.W., and Glosh, M.M. "Abatement of pollution from a poultry processing plant." J. Wat. Pollut. Control Fed., 1972, (44), 1909-1915.

"Details are given of the development of waste treatment scheme for a poultry processing plant, including studies on the characteristics of the waste waters, in-plant changes to reduce the volume and strength of the wastes, and evaluation of alternative treatment methods. Dissolved air flotation was selected as the best method, after coagulation with soda ash and alum, and the treated effluent is chlorinated before discharge; some results of operation of the plant are tabulated and discussed." Typical operating data from a full-scale plant show removals of 74-98 percent BOD, 87-99 percent suspended solids, and 97-99 percent grease. ("Water Pollution Abstracts" 1972, (45), Abstract No. 1788, London: Her Majesty's Stationery Office).

3. Steffen, A.J. "The new and old in slaughter house waste treatment processes." Wastes Engng., 1957, (28).

"Methods of treating slaughterhosue waste waters by screening, sedimentation, the use of septic tanks, intermittent sand filtration, biological filtration and chemical treatment are discussed. Brief descriptions of the newer methods of treatment including the removal of solids and grease by flotation, anaerobic digestion, and irrigation are given." ("Water Pollution Abstracts," 1957, (30), Abstract No. 2414, London: Her Majesty's Stationery Office).

4. Meyers, G.A. "Meat packer tucks wastes unit in abandoned wine cellar." Wastes Engng., 1955, (26)

"At a plant of the H.H. Meyer Packing Co. at Cincinnati, Ohio, processing pork products treatment of the waste waters by dissolved air flotation reduces the amount of grease in the waste waters by about 80 percent and the concentration of suspended solids by 90 percent." ("Water Pollution Abstracts," 1955, (28), Abstract No. 1123, London: Her Majesty's Stationery Office).

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5. Farrell, L.S. "The why and how of treating rendering plant wastes." Wat. & Sewage Wks., 2953, (100).

"In a paper on the treatment of waste waters from plants rendering meat wastes, preliminary treatment by fine screening, sedimentation, and pressure flotation is considered. Screening is economical if recovery of fats is not required. Pressure flotation, which is described fully, is the most efficient method of treatment as judged by the recovery of by-products and conservation of water. Air and coagulants are added to the waste waters in a tank maintained under pressure for solution of air and the waste waters then pass to the flotation unit at atmospheric pressure where dissolved air is liberated carrying solids to the surface. In a typical plant, a removal of 93 percent of the BOD and 93-99 percent of the total fat is achieved. If sedimentation is combined with flotation 93 percent of suspended solids is removed." ("Water Pollution Abstracts" 1953, (26), London: Her Majesty's Stationery Office).

6. Hopkins, E.S., Dutterer, G.M. "Liquid Waste Disposal from a Slaughterhouse." Water and Sew. Works, 117, 7, (July 1970).

"Hopkins and Dutterer reported the results of treating liquid slaughterhouse wastes in a system consisting of screening, grease separation by air flotation and skimming, fat emulsion breaking with aluminum sulfate (26 mg/l) and agitation, oxidation in a mechanical surface oxidation unit provided with extended aeration (24-hr detention time), overflow and recycle of activated sludge, and a final discharge to a chlorination pond (30-min contact). For an average discharge of 23,499 gpd (88.9 cu m/day), the BOD of the waste was reduced from 1,700 to 10.1 mg/l, and most probable number (MPN) coiform counts averaged 220/100 ml." ("Journal Water Pollution Control Federation," 1971, (43), No. 6, p. 949).

7. Dirasian, H.A. "A Study of Meat Packing and Rendering Wastes." Water & Wastes Eng, 7, 5, (May 1970). Sides and quarters delivered from slaughterhosues, Dirasiar found that pressure flotation assisted by aluminum sulfate as a flocculation aid removed grease effectively.

"In a study of a plant that processes finished beef and pork from A recirculation ratio of 4:1 and a flotation period of 20 min were used in these studies. The final effluent showed a 98.5 percent removal of suspended solids (SS) (including grease) with the exception of influent samples containing less than 140 mg/l of SS. In all cases the SS in the effluent was less than 35 mg/l. ("Journal Water Pollution Control Federation," 1971, (43), No.6, p. 949.)

# APPENDIX C

## List of Equipment Manufacturers

### Automatic Analyzers

Hach Chemical Company, P. O. Box 907, Ames, Iowa 50010.

Combustion Equipment Association, Inc., 555 Madison Avenue
New York, N.Y. 10022.

Martek Instruments, Inc., 879 West 16th Street, Newport
Beach, California 92660

Eberbach Corporation, 505 South Maple Road, Ann Arbor,
Michigan 48106

Tritech, Inc., Box 124, Chapel Hill, North Carolina 27514

Preiser Scientific, 900 MacCorkle Avenue, S. W., Charleston,
West Virginia 25322

Wilks Scientific Corporation, South Norwalk, Connecticut
06856

Technicon Instruments Corporation, Tarrytown, New York 10591

Bauer - Bauer Brothers Company, Subsidiary Combustion
Engineering, Inc., P. O. Box 968, Springfield,
Ohio 45501

### Centrifuges

Beloit-Passavant Corporation, P. O. Box 997, Jonesville,
Wisconsin 53545

Bird Machine Company, South Walpole, Massachusetts 02071

DeLaval Separator Company, Poughkeepsie, New York 12600

### Flow Metering Equipment

Envirotech Corporation, Municipal Equipment Division,
100 Valley Drive, Brisbane, California 95005

### Laboratory Equipment and Supplies

Hach Chemical Company, P. O. Box 907, Ames, Iowa 50010

Eberbach Corporation, 505 South Maple Road, Ann Arbor,
Michigan 48106

National Scientific Company, 25200 Miles Avenue, Cleveland,

Ohio 44146

Preiser Scientific, 900 MacCorkle Avenue S.W., Charleston,
West Virginia 25322

Precision Scientific Company, 3737 Cortlant Street, Chicago,
Illinois 60647

Horizon Ecology Company, 7435 North Oak Park Avenue,
Chicago, Illinois 60648

Markson Science, Inc., Box NPR, Del Mar, California 92014

Cole-Parmer Instrument Company, 7425 North Oak Park Avenue,
Chicago, Illinois 60648

VWR Scientific, P. O. Box 3200, San Francisco, California
94119

## Sampling Equipment

Preiser Scientific, 900 MacCorkle Avenue S.W., Charleston,
West Virginia 25322

Horizon Ecology Company, 7435 North Oak Park Avenue,
Chicago, Illinois 60648

Sigmamotor, Inc., 14 Elizabeth Street, Middleport, New
York 14105

Protech, Inc., Roberts Lane, Malvern, Pennsylvania 19355

Quality Control Equipment, Inc., 2505 McKinley Avenue,
Des Moines, Iowa 50315

Instrumentation Specialties Company, P. O. Box 5347,
Lincoln, Nebraska 68505

N-Con Systems Company, Inc., 410 Boston Post Road,
Larchmont, New York 10538

## Screening Equipment

SWECO, Inc., 6033 E. Bandine Boulevard, Los Angeles,
California 90054

Bauer-Bauer Brothers Company, Subsidiary Combustion
Engineering, Inc., P. O. Box 968, Springfield, Ohio
45501

Hydrocyclonics Corporation, 968 North Shore Drive, Lake
Bluff, Illinois 60044

Jeffrey Manufacturing Company, 961 North 4th Street, Columbus, Ohio 43216

Dorr-Oliver, Inc., Havemeyer Lane, Stamford, Connecticut 06904

Hendricks Manufacturing Company, Carbondale, Pennsylvania 18407

Peobody Welles, Roscoe, Illinois 61073

Clawson, F. J. and Associates, 6956 Highway 100, Nashville, Tennessee 37205

Allis-Chalmers Manufacturing Company, 1126 South 70th Street, Milwaukee, Wisconsin 53214

DeLaval Separator Company, Poughkeepsie, New York 12600

Envirex, Inc., 1901 South Prairie, Waukesha, Wisocnsin 53186

Liak Belt Enviornmental Equipment, FMC Corporation, Prudential Plaza, Chicago, Illinois 60612

Productive Equipment Corporation, 2924 West Lake Street, Chicago, Illinois 60612

Simplicity Engineering Company, Durand, Michigan 48429

Waste Water Treatment Systems

Cromaglass Corporation, Williamsport, Pennsylvania 17701

ONPS, 4576 SW 103rd Avenue, Beaverton, Oregon 97225

Tempco, Inc., P. O. Box 1087, Bellevue, Washington 98009

Zurn Industries, inc., 1422 East Avenue, Erie, Pennsylvania 16503

General Environmental Equipment, Inc., 5020 Stepp Avenue, Jacksonville, Florida 32216

Envirotech Corporation, Municipal Equipment Division, 100 Valley Drive, Brisbane, California 95005

Jeffrey Manufacturing Company, 961 North 4th Street, Columbus, Ohio 43216

Carborundum Corporation, P. O. Box 87, Knoxville, Tennessee 37901

Graver, Division of Ecodyne Corporation, U. S. Highway 22, Union, New Jersey 07083

Beloit-Passavant Corporation, P. O. Box 997, Janesville, Wisconsin 53545

Black-Clawson Company, Middletown, Ohio 54042

Envirex, Inc., 1901 S. Prairie, Waukesha, Wisocnsin 53186

Environmental Systems, Division of Litton Industries, Inc., 354 Dawson Drive, Camarillo, California 93010

Infilco Division, Westinghouse Electric Company, 901 South Campbell Street, tuscon, Arizona 85719

Keene Corporation, Fluid Handling Division, Cookeville, Tennessee 38501

Komline-Sanderson Engineering Corporation, Peapack, New Jersey 07977

Permutit Company, Division of Sybron Corporation, E. 49 Midland Avenue, Paramus, New Jersey 07652

## Table 203

Conversion Table

| MULTIPLY (ENGLISH UNITS) | | by | | TO OBTAIN (METRIC UNITS) |
|---|---|---|---|---|
| English Unit | Abbreviation | Conversion | Abbreviation | Metric Unit |
| acre | ac | 0.405 | ha | hectares |
| acre - feet | ac ft | 1233.5 | cu m | cubic meters |
| British Thermal Unit | BTU | 0.252 | kg cal | kilogram - calories |
| British Thermal Unit/pound | BTU/lb | 0.555 | kg cal/kg | kilogram calories/kilogram |
| cubic feet/minute | cfm | 0.028 | cu m/min | cubic meters/minute |
| cubic feet/second | cfs | 1.7 | cu m/min | cubic meters/minute |
| cubic feet | cu ft | 0.028 | cu m | cubic meters |
| cubic feet | cu ft | 28.32 | l | liters |
| cubic inches | cu in | 16.39 | cu cm | cubic centimeters |
| degree Fahrenheit | °F | 0.555(°F-32)* | °C | degree Centigrade |
| feet | ft | 0.3048 | m | meters |
| gallon | gal | 3.785 | l | liters |
| gallon/minute | gpm | 0.0631 | l/sec | liters/second |
| horsepower | hp | 0.7457 | kw | kilowatts |
| inches | in | 2.54 | cm | centimeters |
| inches of mercury | in Hg | 0.03342 | atm | atmospheres |
| pounds | lb | 0.454 | kg | kilograms |
| million gallons/day | mgd | 3785 | cu m/day | cubic meters/day |
| mile | mi | 1.609 | km | kilometer |
| pound/square inch (gauge) | psig | (0.06805 psig+1)* | atm | atmospheres (absolute) |
| square feet | sq ft | 0.0929 | sq m | square meters |
| square inches | sq in | 6.452 | sq cm | square centimeters |
| tons (short) | t | 0.907 | kkg | metric tons (1000 kilograms) |
| yard | y | 0.9144 | m | meters |

* Actual conversion, not a multiplier

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